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A Concept Map Knowledge Model of Intelligence Analysis

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Defence R&D Canada
Technical Memorandum
DRDC Toronto TR 2011-077
May 2011

Canada

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Funding for this research was provided by an Applied Research Program 15dm entitled "Understanding and Augmenting Human Capabilities for Intelligence Production" under the direction of Dr. David Mandel and under the sponsorship of Capt(N) M.J. Barber, Director of Intelligence Capability, Chief of Defence Intelligence.

Abstract

This Technical Report describes a Concept Map (CMap) Knowledge Model (KM) of intelligence analysis developed at DRDC Toronto. The CMap KM consists of a number of interlinked CMaps and over 100 additional resources (such as text documents, images, Internet links, etc.), organized into an interactive hyperlinked system, which serves as a resource depository and provides an easy access to relevant material. The CMap KM captures the research team's conceptual understanding of various issues relevant to intelligence analysis and brings together a number of pertinent topics. The authors' aspiration for this CMap KM is that it might serve as a springboard for further development of concepts essential to intelligence analysis and as a foundation for an intelligence analysis education program.

Résumé

Le présent rapport technique décrit un modèle de schéma conceptuel de la connaissance pour l'analyse du renseignement mis au point à RDDC Toronto. Ce modèle du schéma conceptuel de la connaissance est constitué d'un certain nombre de schémas conceptuels interconnectés et de plus d'une centaine de ressources additionnelles (telles que des documents-textes, des images, des liens Internet, etc.) organisées sous forme de système interactif hyperlié. Ce système sert aussi de dépôt de ressources, ce qui facilite l'accès aux documents pertinents. Le modèle du schéma conceptuel de la connaissance donne un aperçu de la compréhension conceptuelle de l'équipe de recherche sur différents enjeux liés à l'analyse du renseignement et rassemble un certain nombre de sujets pertinents. Les auteurs de ce modèle de schéma conceptuel de la connaissance aspirent à ce qu'il puisse servir de tremplin à un perfectionnement supplémentaire des concepts essentiels à l'analyse des renseignements et servir de fondation à un programme d'éducation en analyse des renseignements.

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Executive summary

A Concept Map Knowledge Model of Intelligence Analysis:

Derbentseva, N.; Mandel, D.R.; DRDC Toronto TR 2011-077; Defence R&D Canada – Toronto; May 2011.

Introduction: Intelligence analysis is an essential function that informs state decision makers. Despite its long history of practice and its significance to state affairs, thorough conceptual understanding of intelligence analysis is lacking. In order to gain a better understanding of various issues involved in the intelligence analysis process, the authors surveyed available literature on intelligence analysis and consulted with intelligence professionals. The authors' conceptual understanding of intelligence analysis was organized in the form of a Concept Map (CMap) Knowledge Model (KM) that brings together a number of topics and resources relevant to intelligence analysis.

Results: The CMap KM of intelligence analysis focuses on those aspects of the intelligence analysis process that affect human performance. The model covers about 20 different topics and identifies and defines dozens of concepts pertinent to intelligence analysis. The model was developed using CMapTools software developed by the Institute for Human and Machine Cognition, Pensacola, Florida, US. The CMap KM of intelligence analysis consists of a number of interlinked CMaps and over 100 additional resources (such as text documents, images, Internet links, etc.), all of which are organized into an interactive hyperlinked system that also serves as a resource depository providing easy access to relevant material.

Significance: The CMap KM of intelligence analysis is a unique collection of conceptual constructs and resources on the topic of intelligence analysis. CMaps, which are the basis of the model, provide visual and concise representation of the concepts and explicate the intended nature of relationships among them. Such representation has a capacity to promote discussion, and it is the authors' intention with this model to generate discussion on a conceptual level within the intelligence community and further develop the model to reflect this discussion. Potentially, CMap KM can become a conceptual hub in the domain of intelligence analysis that would gather all the most pertinent and up-to-date knowledge and resources in an ongoing manner.

Future plans: The CMap KM has been undergoing continuing development to reflect the evolving nature of conceptual understanding. The next step in this model's development will be to modify it to reflect the current framework for the Canadian intelligence analysis training curriculum, which will allow the model to be incorporated into the training program. The authors' aspiration for this CMap KM is that it might serve as a springboard for further development of concepts essential to intelligence analysis and as a foundation for an intelligence analysis education program.

Sommaire

A Concept Map Knowledge Model of Intelligence Analysis:

Derbentseva, N.; Mandel, D.R.; DRDC Toronto TR 2011-077; R & D pour la défense Canada – Toronto; Mai 2011.

Introduction: L'analyse des renseignements est une fonction essentielle qui informe les décideurs d'un État. Malgré le fait que son utilisation remonte à de nombreuses années et en dépit de son importance dans les affaires de l'État, il reste des lacunes dans la compréhension conceptuelle de l'analyse des renseignements. Afin de mieux comprendre des différents enjeux impliqués dans le processus d'analyse des renseignements, les auteurs ont étudié les documents disponibles sur l'analyse des renseignements et ont consulté des professionnels du renseignement. La compréhension conceptuelle de l'analyse des renseignements des auteurs se présente sous la forme d'un modèle de schéma conceptuel de la connaissance qui regroupe un certain nombre de sujets d'analyse de renseignements et de ressources connexes.

Résultats: L'analyse des renseignements du modèle de schéma conceptuel de la connaissance met l'accent sur les aspects du processus d'analyse des renseignements qui touchent la performance humaine. Le modèle couvre une vingtaine de sujets différents, il répertorie et définit des douzaines de concepts relevant de l'analyse des renseignements. Ce modèle a été élaboré grâce au logiciel CMapTools mis au point par l'*Institute for Human and Machine Cognition*, une entreprise située en Floride, aux É.-U. Le modèle de schéma conceptuel de la connaissance pour l'analyse des renseignements est constitué d'un certain nombre de schémas conceptuels interconnectés et de plus d'une centaine de ressources additionnelles (telles que des documents-textes, des images, des liens Internet, etc.), organisés sous forme de système interactif hyperlié. Ce système sert aussi de dépôt de ressource et facilite l'accès aux documents pertinents.

Importance: Le modèle de schéma conceptuel de la connaissance pour l'analyse des renseignements est un regroupement unique de produits conceptuels et de ressources portant sur le sujet de l'analyse des renseignements. Les schémas conceptuels, qui sont la base du modèle, sont une représentation visuelle et concise des concepts; ils expliquent la nature visée des relations entre ces concepts. Une telle représentation a le pouvoir de favoriser la discussion. L'intention des auteurs est que ce modèle serve à amorcer la discussion à un niveau conceptuel au sein de la collectivité du renseignement. Les auteurs veulent aussi poursuivre le développement de ce modèle afin qu'il rende compte de cette discussion. Le modèle de schéma conceptuel de la connaissance a le potentiel de devenir une plateforme conceptuelle dans le domaine de l'analyse des renseignements. Cette plateforme pourrait rassembler de manière continue tous les renseignements les plus pertinents et les plus à jour ainsi que les ressources associées.

Perspectives: Le modèle de schéma conceptuel de la connaissance a fait l'objet de développement continu afin de rendre compte de la nature évolutive de la compréhension conceptuelle. L'étape suivante du développement de ce modèle consistera à modifier le modèle afin qu'il rende compte du cadre actuel du plan de formation canadien en analyse des renseignements, ce qui permettra au modèle d'être intégré dans le programme de formation. Les auteurs de ce modèle de schéma conceptuel de la connaissance aspirent à ce qu'il puisse servir de tremplin à un perfectionnement supplémentaire des concepts essentiels à l'analyse des

renseignements et servir de fondation à un programme d'éducation en analyse des renseignements.

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Acknowledgements

We thank the sponsor of this work, Capt(N) M.J. Barber, Director of Intelligence Capability, Chief of Defence Intelligence, Ottawa, Ontario, Canada. We would also like to thank the members of the Canadian intelligence community that participated in our Concept Map Knowledge Model of intelligence analysis workshop held in February 2010 in Ottawa. Their valuable feedback on the model allowed us to improve its content. Finally, we thank the Institute for Human and Machine Cognition, Pensacola, Florida, US, for developing and providing the CMapTools software, which was used to develop the model.

1 Introduction

This technical report (TR) provides an introduction to Concept Mapping (CMapping) – a knowledge modeling and sharing methodology – and a detailed description of the Concept Map (CMap) knowledge model (KM) of intelligence analysis developed at Defence Research and Development Canada – Toronto (DRDC Toronto). The CMap KM was developed in the context of an Applied Research Program (ARP) project, 15dm, entitled "Understanding and Augmenting Human Capabilities for Intelligence Production." The purpose of the model development was threefold:

- To organize and visually represent the research team's conceptual understanding of intelligence analysis that was acquired during the scoping year of the aforementioned project,
- To create a resource depository that would allow quick access to relevant material (e.g., reports, academic literature, images, and Internet links), and
- To demonstrate the capability of CMapping and the CMapTools[1] software to the Canadian intelligence community (IC).

The authors' conceptual understanding of the topics pertinent to intelligence analysis captured in the CMap KM was primarily derived from two main sources:

- Ongoing interaction with members of the IC, which also includes interviews with Canadian intelligence managers that the research team conducted (Derbentseva et al. 2011), and
- The unclassified research and practitioner literature on intelligence analysis.

We chose CMapping as a knowledge representation medium for encoding the model because of its compatibility with the purposes of the task outlined above and the properties of the knowledge domain to be represented, i.e., the conceptual understanding of intelligence analysis. CMapping is a knowledge representation method that has an established track record of application in a variety of domains (Cañas et al. 2004b, Cañas and Novak 2006, Cañas et al. 2008, Sánchez et al. 2010) including knowledge engineering and management (Hoffman and Lintern 2006, Moon et al. 2009). CMapping allows a user to create a knowledge representation that is visual, concise, and fairly intuitive (at least to the map developer). These features enable users to readily understand CMaps without any prior training. CMap representation aids in externalising and communicating knowledge, which prompts discussion and can support conceptual development of a domain. The representational structure of CMaps draws attention to the relationships among concepts, and can specify a wide range of conceptual relationships. Thus CMapping is well positioned to support knowledge modeling in domains such as intelligence analysis, which do not have precisely defined or quantified relationships among the concepts, and require the flexibility of the free-form representation of relationships. Supported with dedicated software packages, such as CMapTools, CMap KM can be designed as an interactive knowledge and resource depository system that can support knowledge sharing and management.

[1] CMapTools software was developed at the Institute for Human and Machine Cognition (IHMC), Pensacola, Florida, US.

We began developing the CMap KM for intelligence analysis in 2009, and the CMap KM was introduced to a select group of Canadian intelligence experts during a DRDC Toronto workshop in February 2010 (Derbentseva and Mandel 2011, Gauthier 2010). The model is being incrementally developed over time, and the present technical report documents the state of the model at the time of writing.

This report is organized in the following manner: Section **2** provides a brief overview of CMapping and the CMapTools software; Section **3** describes the model; and Section **4** offers concluding remarks.

2 Overview of Concept Mapping

2.1 What is a CMap?

A CMap is a tool that allows a user to represent knowledge in a graphical form. CMapping is based on the notion that the essence of our knowledge is in the interconnections that are formed among different concepts that we acquire over time, and a CMap graph makes these conceptual relationships explicit. A CMap is a subjective representation of its creator's knowledge structure; therefore, two individuals might construct two different maps on the same topic depending on their understanding and interpretation of that topic.

CMapping is a method of knowledge diagramming, which results in a final product – a CMap. We refer to the process of constructing a CMap as CMapping, thus making a distinction between the process (i.e., CMapping) and the product (i.e., a CMap). CMaps combine textual and graphical elements to convey meaning. They have the form of semi-hierarchical graphs of nodes and edges that represent the map creator's conceptual understanding of the map's topic (see *Figure 1*). The term "concept map" has been loosely used to refer to a variety of node-link-node representations; however, in this report we use the term CMap or CMapping to refer to particular types of node-link-node diagrams – "Novakian" CMaps. The Novakian CMaps have a set of distinguishing properties, such as their propositional coherence, syntax and semantics, morphology, and inclusion of a focus question, which are discussed in Sub-section **2.3**. A brief history of Novakian CMapping is given in Sub-section **2.2**. Sub-section **2.4** discusses the process of CMap construction, and Sub-section **2.5** describes IHMC's CMapTools software – the software that was used to create the CMap KM of intelligence analysis.

2.2 Brief history of the development of CMaps

CMaps were developed at Cornell University, Ithaca, New York, in the 1970s by a research team of educational psychologists led by Joseph D. Novak (Novak and Gowin 1984, Novak and Musonda 1991, Novak and Cañas 2006). Novak's team studied conceptual changes in children, and CMaps were originally developed as a research method to capture these changes. Since then, CMaps have been developed into a method to support and promote meaningful learning (as opposed to rote learning). The origin and subsequent development of CMaps is based on the learning theory of Ausubel (1963), which emphasises the role of assimilation of new knowledge into the learner's existing knowledge structure in the process of learning meaningfully (Novak and Cañas 2008). Some of the fundamental processes involved in assimilation of new knowledge are subsumption (i.e., establishing relationships between the old knowledge and new information), differentiation (i.e., establishing differences between the new concepts and the old ones), and reconciliation (i.e., resolving conflicts between the new and existing concepts). CMap representation exposes relationships among concepts that the map author possesses, which provides an insight into his or her knowledge structure.

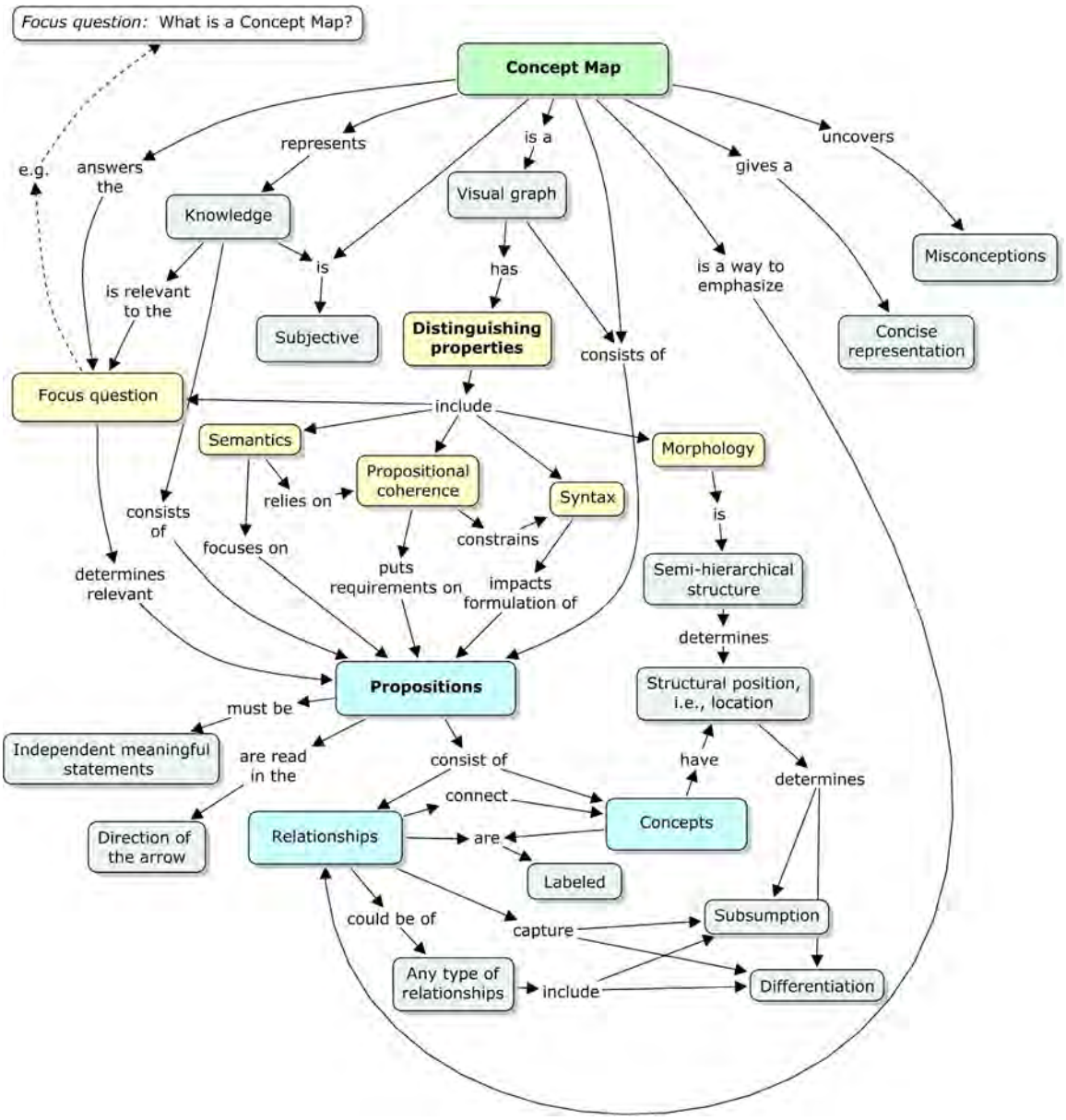

Figure 1: A CMap about CMaps

Since their development, CMaps have been widely applied in education as a tool for both teaching and evaluation in a variety of subjects (e.g., science, mathematics, languages, and history) spanning from preschool to higher education levels (e.g., Cañas et al. 2008, Sánchez et al. 2010). Since 2005, CMaps have been adopted as a main pedagogical tool in the education system of Panama (Tarte 2006). Although the main application of CMaps reported in the literature is in education, CMaps also have been applied in industry and government organizations for various knowledge management activities, such as the development of expert systems, knowledge elicitation, knowledge preservation, knowledge sharing, and knowledge engineering (e.g., Coffey et al. 2003, Hoffman and Lintern 2006, Moon et al. 2011).

The research on CMapping is published in academic journals and edited volumes on various topics, such as research on teaching and education (e.g., Derbentseva et al. 2007, McClure et al. 1999, Novak and Musonda 1991), expertise research (e.g., Hoffman and Lintern 2006), cognitive task analysis (Crandall et al. 2006), expert systems (e.g., Coffey et al. 2003), and knowledge visualisation (e.g., Cañas et al. 2005, Sherborne 2008). Four bi-annual international conferences that were exclusively devoted to CMapping have taken place since 2004. These conferences attracted hundreds of educators, scholars, and practitioners (see Cañas et al. 2004b, Cañas and Novak 2006, Cañas et al. 2008, Sánchez et al. 2010 for proceedings). The next CMapping conference is planned for 2012. Software tools that support electronic CMap construction and sharing, such as CMapTools, considerably facilitate application of CMapping in various contexts. With the growing interest in methods for knowledge and information visualisation, application of CMapping is likely to continue expanding.

2.3 Components and properties of CMaps

The main components of a CMap are its focus question and the concepts and relationships that form the propositions of which a map is comprised. CMaps also have a number of properties that uniquely position them among other node-link-node visual-textual representations, such as Mind Maps (Buzan and Buzan 1994), influence diagrams (Miller et al. 1976), and conceptual graphs (Sowa 2000). The main properties of CMaps include propositional coherence, syntax, and morphology. These components and properties are discussed below.

- **Focus question:** When a CMap is constructed, it is done so with a particular purpose in mind. More precisely, the map is constructed for a certain audience and to answer a specific question called the focus question. For example, the focus question of the CMap in *Figure 1* is "What is a Concept Map?" The focus question is a vital piece of information for any given map because it explicitly defines the topic and sets the boundaries for a map's content. A clearly formulated focus question helps to keep a map focused during its construction and provides the necessary contextual information to the map reader. Unfortunately, published maps often do not include their focus question, thus allowing the context and the purpose of the map to remain vague or ambiguous.

- **Concepts:** The (rounded) boxes – *nodes* – in CMaps represent concepts. Novak defines a concept as "perceived regularities in events and objects" (Novak and Gowin 1984, Novak and Cañas 2008). Concepts are labelled with words and/or symbols and could be stated as a single word or a phrase. For example, concepts such as "knowledge", "focus question", and "propositions" are shown in nodes in the CMap of *Figure 1*.

- **Relationships**: In CMaps, as in many other node-link-node graphs, nodes are connected, indicating the presence of a relationship between two concepts. CMaps, however, require that the nature of the relationship between concepts is explicitly stated on the lines with linking phrases. Linking phrases that specify the nature of relationship between concepts in CMaps should be well articulated and as specific as possible.

    - ***Types of relationships***: There are no restrictions on the types of relationships that can be represented in CMaps. A number of node-link-node representations, such as Mind Maps, influence diagrams, argument maps, and conceptual graphs to name a few, either do not specify the nature of relationship among concepts (which implies that all relationships are of the same type, e.g., "is related to" or "influences") or

allow only a limited set of relationships to be represented (e.g., "is a" or "has attribute"). In CMaps, both concepts and relationships must be labelled, and no restrictions are imposed on the types of concepts and relationships that can be expressed. The requirement to specify relationships enforces clarity onto the intended meaning and removes ambiguity associated with the necessity to interpret the unspecified components. The lack of constraints on the types of relationships in CMaps allow for a great flexibility of representation. For example, the same CMap can include logical, classificatory, and other subsumption or differentiation relationships. In addition, the relationships can be specified at different levels of precision, and could include numerical values in addition to word labels (e.g., probability of the relationship). The lack of imposed restrictions on conceptual relationships contributes to the expressive potential of CMaps (Hoffman 2008).

- ***Directional relationships***: Relationships among concepts in CMaps are stated on the directional lines that connect them. Often, lines have arrows that specify the direction, however, when the arrowheads are omitted, the top-down direction is assumed. Often, relationships between concepts are not symmetrical (e.g., see *Figure 2* and *Figure 3*), and the line's direction indicates the direction of the relationship between the two concepts.
- ***More than one relationship between two concepts***: It is often the case that a pair of concepts has several distinct relationships rather than just one. The choice of which relationship between two concepts should be represented in a map depends on the map's context, which is defined by its focus question, other concepts and relationships already included in the map. If needed, CMaps allow including more than one relationship between a pair of concepts. In this case, several lines connect the same pair of concepts and each distinct relationship between the concepts is stated on a separate line.
- ***Which concepts should be connected*:** It is possible to connect any two concepts in one way or another (e.g., with an ambiguous "is related to" linking phrase). However, if a CMap included all possible relationships among its concepts it would become overcrowded, which would make it very hard to read. Such a map would not provide a good answer to its focus question. The CMap's focus question plays a vital role in determining which relationships are necessary and sufficient for a given map. The selection and formulation of relevant and meaningful relationships among concepts is critical for constructing a good CMap.

- **Propositions:** CMaps have a propositional structure. Propositions in CMaps are node-link-node triads, which form independent meaningful statements (i.e., propositions in CMaps are units of meaning). Propositions are read in the direction of the arrow, which means that the directionality of the arrow overrides the conventional reading/writing rules. That is, propositions might be read from bottom to top or from right to left if the arrow indicates that direction. There is no constraint on the direction of the links, i.e., an arrow may point in any direction. If an arrowhead is absent on a line, the proposition is read from top to bottom. Each node-link-node triad has to form a meaningful statement when read in the direction of the arrow. For example, the proposition in *Figure 2* is read "*smoking can lead to cancer*".

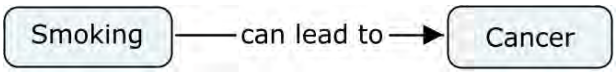

Figure 2: Directionality of concept relationships: Example 1

However, if the directionality of the arrow is reversed, as in *Figure 3*, the proposition will no longer represent the same meaning, e.g., the proposition in *Figure 3* is read "*cancer can lead to smoking*", which obviously differs in meaning from the proposition expressed in *Figure 2*.

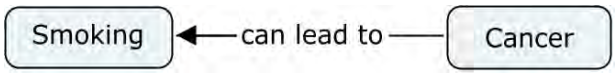

Figure 3: Directionality of concept relationships: Example 2

- **Propositional coherence:** The notion of propositional coherence in CMaps requires that CMaps have a propositional structure and that each proposition (i.e., each node-link-node triad), on the one hand, forms a meaningful statement, and on the other hand, is independent from other concepts and relationships in the map. This implies that each node-link-node triad, taken out of the map, remains an independent meaningful statement that can be classified as either true or false (although the meaning of a proposition may change when taken out of the CMap's context). *Figure 4* provides an example of a CMap that does not have a propositionally coherent structure (Kinchin 2008). For example, the proposition male parts – to → female parts would be meaningless outside of the context of the entire map (or without at least some of its neighbouring propositions).

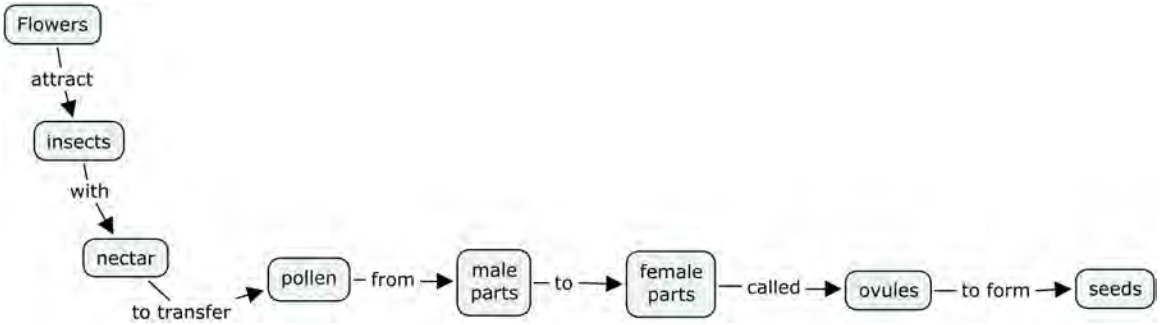

Figure 4: An example of a poorly constructed map (Kinchin 2008)

It is worth noting that a CMap's propositional structure is not equivalent to (and does not map well onto) the linear structure of a sentence, i.e., slicing a sentence into noun-phrases and putting them into boxes that are connected with verbs used in the sentence does not necessarily constitute a propositionally coherent structure. The CMap in *Figure 4* is an example of a poor map constructed with no alteration to the original sentence's linear structure. *Figure 5* provides an example of how the linear structure of the CMap in *Figure 4* can be transformed into a propositionally coherent map with a network structure (Kinchin 2008).

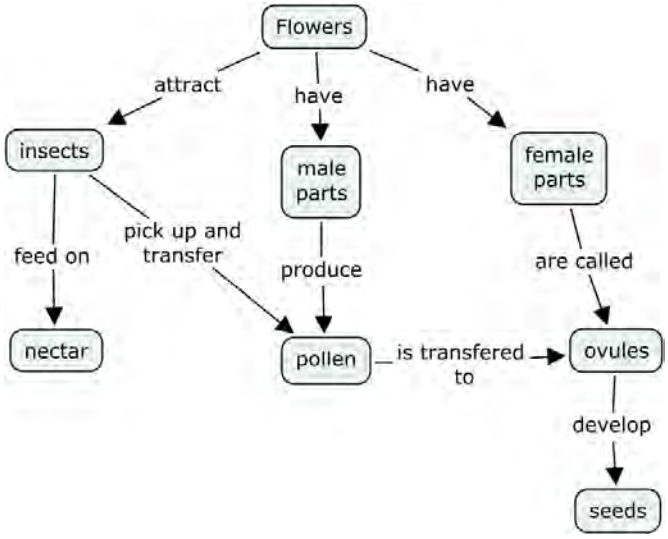

Figure 5: An example of a propositionally coherent representation of the CMap in Figure 4 (Kinchin 2008).

Creating a propositionally coherent structure in a CMap requires unpacking any tacit concepts and propositions that may be implied in natural language. For example, a noun phrase extracted from a sentence, e.g., "my car," does not constitute a single concept as might seem at first, but contains two concepts connected with an implied relationship, thus forming a proposition: [I] – have → [car]. Adherence to the propositional coherence principle exposes not only the meaning that is explicitly stated in a sentence, but also the one that is implied. Although, in principle, a good CMap is supposed to expose all implicit concepts and relationships, in practice this might be infeasible because the map might become immense.

- **Syntax:** Both concepts and relationships in CMaps are labelled. Because concepts represent regularities in events or objects, concept labels are not restricted to any particular part of speech (e.g., concept labels can contain nouns, pronouns, adjectives, verbs, etc.). In addition to words, symbols can also be used to label concepts and relationships. Propositional coherence imposes certain constraints on the overall structure of propositions. Given that propositions have to be independent meaningful statements, linking phrases usually contain verbs or verb phrases; and there must be an agreement between the concepts and the linking phrase.
- **Morphology:** According to Novak and colleagues (Novak and Gowin 1984, Novak 1998, Novak and Cañas 2008), CMaps have a semi-hierarchical structure. The most important concept in the map, which is also called the root concept, is represented at the top followed by more general and important concepts that provide the context for the root concept and the overall map. More specific concepts are included towards the bottom of the map. Thus, the meaning of concepts included in a map is defined (or constrained) by other concepts and propositions that situate a given concept in a particular context.
  - **Cross-links**: One of the main features of CMaps' morphology is cross-links. Cross-links are propositions that connect concepts in different segments of a map, and reach across the hierarchy. Constructing cross-links requires noticing relationships

between seemingly unrelated sub-parts of a map – an activity that has been associated with creativity and knowledge discovery (Novak 1998).

Although CMaps usually have a semi-hierarchical structure, there is no constraint on the type of structure a CMap can assume – it can be hierarchical, networked, cyclical, chained, or a combination of different types. A CMap's organization should suit its content, and the chosen structure for a map can influence the content that will be represented in it (Derbentseva et al. 2007).

2.4 CMapping: The process of CMap construction

Constructing a CMap requires the map author to clarify the meaning of relevant concepts and relationships and his or her own understanding of the topic. The process of CMap construction can be as important as its product (i.e., a CMap) as it may be seen not only as a path to a goal, i.e., producing a CMap, but it could also be seen as a goal in itself, i.e., achieving greater clarity on a given topic through map construction. Learning to construct a good CMap is not an easy process and it requires practice.

CMaps can be constructed with paper and pencil, post-it notes and a board, or using one of the many suitable software packages. Constructing CMaps electronically, however, has a number of advantages, including the ease of editing and sharing, the ability to attach resources to concepts and relationships, and the ability to create knowledge models of interlinked CMaps.

A step-by-step method of CMapping modified from Novak and Cañas (IHMC 2006, Novak and Cañas 2008) is outlined in *Figure 6*. This process is generic and could be applied to any mode of CMapping. The process of CMap construction begins with the formulation of a focus question for the map, which is used as a reference point for generating a list of the most relevant concepts to the topic. This list of concepts, not yet connected, is called a "parking lot." The concepts in the parking lot are then rank ordered in terms of their relevance and the top two to four most relevant concepts are used for constructing the first propositions. While constructing propositions, it is important to select clear and specific linking phrases and ensure that propositional structure is maintained in the map. After the selected few most relevant concepts are connected to each other, other concepts are added from the parking lot to the structure and related to other concepts forming propositions. It is suggested that the mapper should periodically revisit the structure and evaluate the relevance of the included propositions to the focus question. Unsubstantial links might be removed from the structure and missing links might be added. The mapper is also encouraged to look for potential cross-links (i.e., relationships among concepts in different segments of the map).

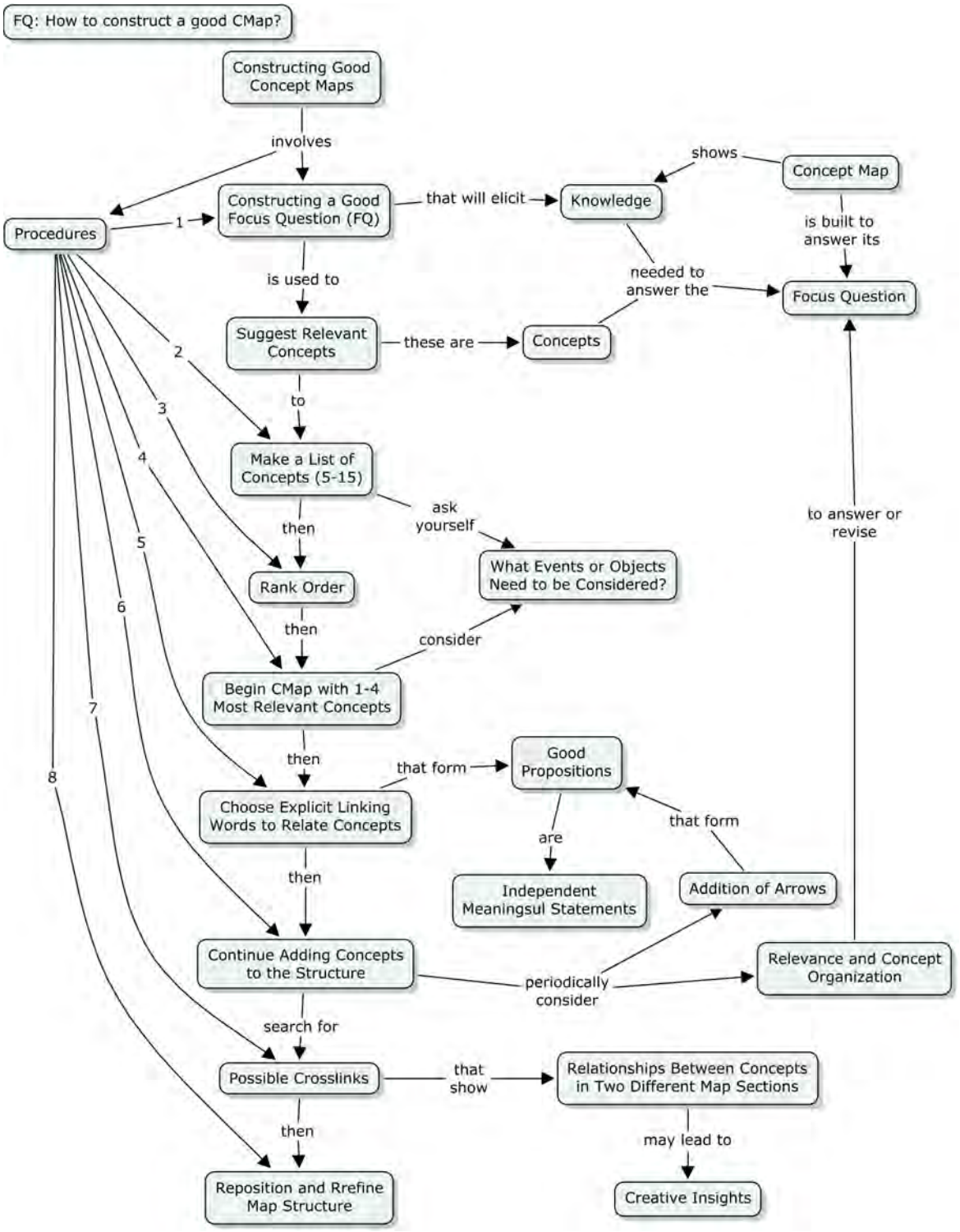

Figure 6: Steps in building a CMap, a CMap- Flow Chart hybrid, modified from IHMC (2006)

The process of adding concepts to the structure and evaluating its relevance to the focus question continues until all concepts in the parking lot are used (or discarded). At this point, the map is re-evaluated with respect to the focus question, and further modifications to the structure could be made, including addition or deletion of concept and links. When the mapper is satisfied with the content of the map, its shape may be refined to optimize the spatial arrangement of the map's elements and reduce the number of crossing links. The process of map refinement, including adjustments to concepts and relationships, can continue indefinitely. Some practitioners argue that because CMaps represent knowledge, they never constitute a finished product, because knowledge is constantly evolving, and, thus, its representation (i.e., the CMap) must be evolving with it.

Further discussions of the methods of how to construct CMaps are available in Novak and Cañas (2008), Hoffman (2008), and Crandall et al. (2006).

2.5 CMapTools software

CMapTools software, developed by IHMC, was used to create the CMap KM of intelligence analysis. CMapTools is available free for commercial or non-commercial use from the IHMC's website at http://cmap.ihmc.us/download/. CMapTools is a software environment specifically designed for CMap construction and sharing; it has a client-server architecture that enables publishing CMaps and CMap KM in concept map servers, making the maps and KMs accessible from any computer station with the Internet access and CMapTools software installed.

CMapTools has a low threshold, i.e., a system which is relatively easy to learn how to use, and a high ceiling, i.e., a system with ample capabilities for supporting CMapping (Cañas et al. 2004a).

The CMapTools environment allows enhancing CMaps by attaching additional resources to concepts and relationships, e.g., images, texts, video and audio files, and Internet links, and enables the construction and sharing of CMap KMs. CMap KMs are collections of interlinked CMaps on a given topic and all the additional resources included in the maps. Various resources are linked to map components by attaching icons that group resources by type, e.g., all CMaps attached to a given concept are grouped under the CMap icon; all texts are grouped under the text icon, etc. For example, the concept "structured analytic technique" in *Figure 7* has two icons attached to it indicating that there are two types of resources attached to this concept: texts and CMaps. Clicking on the text resource icon, for example, will open up a list of all text documents that are attached to the concept; and clicking on one of the documents from the list will open the document in a separate window.

The client-server architecture of CMapTools allows creating shared places for CMaps and CMap KMs, which promotes and supports collaboration. Users can access shared places through Internet or Intranet, and can collaborate on construction of CMaps and CMap KMs through the "collaborate" tool of the CMapTools software. Users can also use places to share their CMaps and to access and comment on others' maps and KMs. In addition, CMapTools facilitates CMap sharing with its capability to convert CMaps into several common file formats, such as image, web page, comma delimited text file, PDF, and XML.

3 CMap KM of intelligence analysis

3.1 Conceptual description of the model

3.1.1 Model's content

The KM of intelligence analysis is the product of the scoping year of an ARP project that aims to understand and augment human capabilities in intelligence production. The model is the outcome of our learning about intelligence analysis from our interactions with intelligence professionals and the survey of academic and practitioner literature. The goals of the ARP project guided our investigation of intelligence analysis and these goals are also reflected in the choice of topics that are included in the KM. The CMap KM of intelligence analysis is primarily a conceptual model designed to identify and relate a set of concepts that are central to different topics associated with human capabilities in intelligence analysis. The model serves as an organizing framework for relevant ideas and resources associated with them. If, as we hope, the model is adopted and further developed within the IC, it could, ultimately, facilitate conceptual development in the area of intelligence analysis and could be used to support analyst training as we discuss further in Sub-section **3.1.4**.

The entry point into the model is the CMap "Intelligence analysis" (*Figure 16*), which provides an overview of the included topics. Currently, the model includes 23 CMaps, which are listed by topic in *Table 1,* short description of each map is provided in Sub-sections **3.1.2.1 – 3.1.2.22,** and their images shown in *Figures 7 – 29* are provided in **Annex A**.

In agreement with the priorities of the ARP project, the model focuses on the human aspect of the intelligence analysis process. Understanding human behaviour requires examining the interaction between person and environmental factors (Brunswik 1943, Heider 1958, Lewin 1935), which is reflected in the composition of the topics included in the KM. About half of the CMaps currently included in the model focus on the individual actors involved in the process (i.e., intelligence analyst, consumer of intelligence products, intelligence manager, and intelligence collector) and elaborate on:

- Characteristics of the actors, e.g., CMap "Analysts' skills" (*Figure 8*);
- Tasks that individual actors perform, e.g., CMaps "Analysts' tasks" (*Figure 9*) and "Managers' tasks" (*Figure 28*), including the available tools that support task performance, e.g., CMaps "Analytic tools" (*Figure 10*) and "ACH" (*Figure 7*).
- Various issues with which individual actors deal, e.g., CMaps "Cognitive issues in analysis" (*Figure 13*) "Intelligence collection" (*Figure 17*), "Intelligence consumer" (*Figure 18*), "Issues in information search and evaluation" (*Figure 24*), and "Management issues" (*Figure 27*); and
- Relationships and coordination among the individual actors, e.g., CMaps "Main players in intelligence analysis" (*Figure 26*) and "Coordination issues" (Figure 14).

The other half of the model's CMaps focus on the context in which intelligence analysis is conducted, including organization of the process with its demands, constraints, and requirements. These maps elaborate on:

- Purpose of intelligence analysis and intelligence requirements, e.g., CMaps "Purpose of intelligence analysis" (*Figure 29*) and "Intelligence requirements" (*Figure 23*);
- Processes involved, e.g., CMaps "Main elements and processes in intelligence analysis" (*Figure* 25), "Intelligence cycle" (*Figure* 19), "Intelligence analysis" (*Figure 15)*, "Intelligence evaluation" (*Figure 20*), "Assessment difficulty" (*Figure 11* and *Figure 12*), and "Issues in information search and evaluation" (*Figure 24*);
- Outcomes of the process, e.g., CMap "Intelligence products" (*Figure 22*); and
- The composition of the Canadian intelligence community, e.g., CMap "Intelligence organizations" (*Figure 21*).

Table 1: List of CMaps in the CMap Knowledge Model of Intelligence Analysis

#	Map Topic	Root Concept	Focus Question	C[1]	P[2]	L[3]
1	ACH	ACH (Analysis of Competing Hypotheses)	What are the main premises of ACH?	24	45	9
2	Analysts' skills	Essential skills	What are the essential skills for intelligence analysts?	28	27	9
3	Analysts' tasks	Intelligence analyst	What are the main tasks of intelligence analysts?	30	54	19
4	Analytic tools	Analytic tools	What do we know about analytic tools?	51	59	47
5	Assessment difficulty	Degree of intelligence assessment difficulty	What factors contribute to the difficulty of intelligence assessment?	28	37	7
6	Assessment difficulty (tree)	Degree of intelligence assessment difficulty	What factors contribute to the difficulty of intelligence assessment?	35	40	8
7	Cognitive issues in analysis	Cognitive Issues in analysis	What are some of the cognitive issues in intelligence analysis?	32	35	15
8	Coordination issues in the intelligence process	*No distinct root concept*	What are possible coordination issues in intelligence analysis?	7	17	13
9	Intelligence analysis	Analysis	What are the issues in the intelligence analysis and areas of research that might help addressing them?	61	110	32
10	Intelligence analysis [Top map][4]	Intelligence analysis	What is intelligence analysis?	21	23	51

11	Intelligence collection	Intelligence collection	What are the issues in intelligence collection?	24	34	13
12	Intelligence consumer	Intelligence consumer	What are some of the possible constraints in intelligence consumer's environment?	20	29	14
13	Intelligence cycle	Intelligence cycle	How is the intelligence production process conceptualized?	17	20	52
14	Intelligence evaluation	Evaluation of intelligence	What are the issues in evaluation of intelligence?	17	17	10
15	Intelligence organizations	Canadian intelligence community	Who are the main players in the Canadian intelligence community?	19	18	13
16	Intelligence products	Intelligence products	What are the types of intelligence products?	21	31	14
17	Intelligence requirements	Intelligence requirements	What are the properties of intelligence requirements?	13	21	10
18	Issues in information search and evaluation	Information search	What issues are involved in information search and evaluation?	19	33	9
19	Main elements and processes in intelligence analysis	*No distinct root concept*	What are the main elements and processes in intelligence assessment?	26	46	20
20	Main players in intelligence analysis	*No distinct root concept*	What are the interactions between the main players in intelligence assessment?	5	16	13
21	Management issues	Intelligence managers	What are the prevailing issues that intelligence managers face?	15	18	14
22	Managers’ tasks	Intelligence manager	What are the manager's tasks in intelligence production?	17	28	24
23	Purpose of intelligence analysis	Purpose of intelligence analysis	What is the purpose of intelligence analysis?	17	21	13

1 – column C lists the number of concepts in a map.

2 – column P lists the number of propositions in a map. A proposition is a concept-link-concept triad.

3 – column L lists the number of links, i.e., external resources attached to a map. Resources include links to other CMaps, Internet pages, and hyperlinks to various types of files such as images, audio, video, and text files.

4 – Top map is the main map of the model that provides an overview of included topics and serves as the entry point into the model.

It is worth noting, that the dichotomy of the model's topics suggested above, while being helpful in describing the model's content, should not be taken to imply that the topics in the two groups are mutually exclusive. In fact, there is a great deal of interaction between the individual and the contextual factors, and each map includes concepts relevant to both. The CMaps were grouped into the two categories based on their overall emphasis on either individual or contextual factors.

The set of topics included in the KM is by no means exhaustive – it includes only topics that are predominantly focal to the ARP, and on which information was available. Additional maps could be developed on other topics, which are currently included in the KM only as individual concepts. For example, the CMap on analytic tools contains a concept, *Analytic Rigour*, a topic which has been developed into a CMap of its own, but is not currently included in the model.

The KM is organized in a manner that allows easy access to topics related to each other (e.g., analyst's tasks and application of analytic tools); the KM's organization is described in more detail in Sub-section **3.1.3**. A brief description of each map's content included in the KM is provided in Sub-section **3.1.2** below.

3.1.2 The content of the CMaps

This section provides a short description of each CMap's content and includes a list of the most interconnected concepts in each map. The most interconnected concepts are identified based on the total number of incoming and outgoing links a concept has with other concepts of the map, and is a unidirectional measure of degree centrality computed in network analysis. The list of the most interconnected concepts in each map illustrates central ideas of the map. CMaps in this section are listed in the same order as in *Table 1* and **Annex A**.

3.1.2.1 CMap 1: ACH (*Figure 7*)

This map provides a description of the main premises of the ACH technique, such as externalization and decomposition of hypotheses, evidence and assumptions, falsification of hypotheses, and construction of the ACH matrix. Red color is used in the map to highlight concepts and relationships, which may undermine the effectiveness of the ACH method and require further investigation. This map has a semi-hierarchical structure and includes many links and cross-links. The most interconnected concepts of this map are *Evidence* (11 links), *ACH* (nine links), *Hypotheses* (eight links), *ACH matrix* (seven links), and *Falsification* (seven links).

3.1.2.2 CMap 2: Analysts' skills (*Figure 8*)

This map lists essential skills required of intelligence analysts that were identified by Canadian intelligence managers that we interviewed (Derbentseva et al. 2011). The essential skills are grouped into four general categories: analytic skills, environmental suitability, knowledge, and characteristics. This map has a purely hierarchical structure with only five concepts having more than one link: *Characteristics* (seven links), *Essential skills* (seven links), *Analytic skills* (six links), *Environmental suitability* (six links), and *Knowledge* (five links).

3.1.2.3 CMap 3: Analysts' tasks (*Figure 9*)

This map provides an overview of general groups of tasks that intelligence analysts perform, including interactions with his or her intelligence manager and the IC, staying on top of the developments in his or her subject area, conducting information search and evaluation, conducting analysis, preparing intelligence products. This map is designed to illustrate the breadth of analysts' activities rather than providing sufficient detail on any of them. More detailed CMaps could be constructed on each task to examine it further. This map has a semi-hierarchical structure with the most interconnected concepts being *Intelligence analyst* (twelve links), *Intelligence products* (seven links), *Analysis* (six links), and the three concepts of *Analytic methodology*, *Reasoning*, and *Structured analytic tools* having four links each.

3.1.2.4 CMap 4: Analytic Tools (*Figure 10*)

This map includes a list of 29 analytic techniques from the Aide Memoire on Intelligence Analysis Tradecraft (Thompson 2009), which are grouped based on their functions into three categories: diagnostic, challenge, and imaginative techniques. In addition, the map contains a section addressing the general purpose of analytic techniques, and a section on factors affecting their application. The map has a semi-hierarchical structure with the most interconnected concepts being *Analytic tools* (21 links), and the three concepts representing the categories of the techniques: *Imaginative techniques* (15 links), *Diagnostic techniques* (11 links), and *Challenge techniques* (ten links).

3.1.2.5 CMaps 5 and 6: Assessment difficulty and Assessment difficulty (tree) (*Figure 11* and *Figure 12*)

CMaps 5 and 6 describe the factors that contribute to the difficulty of intelligence assessments, and the concepts contained in the two maps are very similar. The main difference between them is in the maps' structure and relationships among the concepts. CMap 6 has a traditional semi-hierarchical CMap structure with predominantly classificatory relationships among the concepts. Different factors contributing to the assessment difficulty are grouped under three major categories of characteristics – task, setting, and individual. CMap 5, on the contrary, has no pronounced hierarchy and predominantly *dynamic* relationships among concepts that portray how change in one concept affects the other concept in the proposition (for a discussion on dynamic relationships in CMaps, see Safayeni et al. 2005). Dynamic relationships, such as those included in CMap 5 could be expressed in more precise terms (e.g., as an equation, or including a coefficient) if such information was available.

The two maps also differ somewhat in their most interconnected concepts. The network-structured CMap 5 has as its most interconnected concept the concept *Uncertainty* with ten links, which has only three links in CMap 6. Furthermore, only two concepts overlap among the five most interconnected concepts in the two maps – *Intelligence problems taxonomy* and *Quantity of available information* – both have six links in both maps.

The two maps on the same topic are included in the model to demonstrate the flexibility of CMaps and the range of conceptual relationships that can be expressed with them.

3.1.2.6 CMap 7: Cognitive issues in analysis (*Figure 13*)

The CMap on cognitive issues includes concepts relevant to such issues as mirror imaging, confirmation bias, decision avoidance, information overload, difficulty in foreseeing uncharacteristic events, poor logic and lack of rigour, and difficulty in accepting alternative perspectives on the problem. The cognitive issues included in this CMap were limited to those identified by the intelligence managers that we interviewed. However, the map could be expanded to include other relevant issues. The map has a semi-hierarchical structure with its most interconnected concepts being *Cognitive issues* in analysis (nine links), *Decision avoidance* (seven links), *Information overload* (six links), and *Foreseeing uncharacteristic events* (five links).

3.1.2.7 CMap 8: Coordination issues in the intelligence process (*Figure 14*)

This map portrays the interdependency relationships among different players involved in the intelligence production process, i.e., intelligence analyst, intelligence manager, intelligence consumer, and intelligence collector. Potential coordination issues are represented with dashed red lines. This map has more of a network structure rather than a customary semi-hierarchy and does not have an evident root concept. The most interconnected concepts of this map are *Information needs* (six links), *Intelligence analysts* (six links), *Intelligence collectors* (six links), *Potential issues* (six links), and *Intelligence requirements* (five links).

3.1.2.8 CMap 9: Intelligence analysis (*Figure 15*)

This map is the largest map of the model, which includes a variety of concepts related to intelligence analysis. This map has links to all other maps of the model indicating that, to a certain extent, it covers all the topics included in the model. This map captures topics covered in other CMaps of the model and showing how their concepts interrelate among each other. In addition, this map includes 13 concepts (enclosed in ovals with green borders on the edges of the map) that outline areas for further research and development to support and advance our knowledge of issues pertinent to intelligence analysis. The map has an elaborate network structure with many cross-links. The concept *Analysis* is in the center of the map and is the most interconnected concept with 23 links. Other most interconnected concepts of this map are *Information search* (ten links), *Information evaluation* and *Intuitive/individual approach* with eight links each, and *Cognitive processing*, *Intelligence analyst*, *Intelligence consumers*, *Intelligence manager*, *Intelligence products*, *Intelligence requirements*, and *Vast quantity of information* each with seven links.

The KM development began with this map, which was later broken down into smaller, more coherent, and easier to read maps, which were further elaborated. This map is included in the model in its current form to demonstrate possible complexity of CMaps.

3.1.2.9 CMap 10: Intelligence analysis [Top Map] (*Figure 16*)

This map in an entry point for the model and it provides an overview of the included topics, such as intelligence products, production process, activities and tasks, information, organizations engaged in intelligence analysis, application of analytic tools, cognitive issues, and the different

roles involved in the intelligence production process, i.e., analysts, managers, consumers, and collectors. Because of its function, this map has a star structure with the *Intelligence analysis* concept located in the middle and other concepts representing topics of the model located around it. Not many connections are included among the satellite concepts so as not to overcrowd the map. In such a structure, the concept Intelligence analysis is also the most interconnected concept with nine links and all the remaining concepts have four or fewer links each. This map has links to all other CMaps in the KM.

3.1.2.10 CMap 11: Intelligence collection (*Figure 17*)

This map lists a set of issues that may be associated with intelligence collection, such as ambiguity of purpose and requirements, difficulty in evaluating source reliability and information accuracy, deception, cultural differences, etc. In addition, it identifies possible factors that may contribute to the mismatch between the intelligence requirements and the collected intelligence, such as a lack of open communication between the requirements generators and intelligence collectors. The map has a semi-hierarchical structure, and its most interconnected concepts are *Issues in intelligence collection* (15 links), *Intelligence collection* (eight links), *Available resources* (six links), and *Intelligence requirements*, *Lack of open communication*, and *Requirements originators* with five links each.

3.1.2.11 CMap 12: Intelligence consumer (*Figure 18*)

Intelligence products are produced for use by intelligence consumers, and are intended to inform the consumers and provide them with useful information. Among other things, the quality of intelligence requirements and feedback from the consumer affect whether or not an intelligence product provides useful information. CMap 12 examines possible constraints in the intelligence consumer's environment that may have an impact on usefulness of intelligence products, such as changing priorities, available information from other sources than intelligence, short timelines and difficulty in articulating intelligence requirements. The map has a semi-hierarchical structure with its root concept *Intelligence consumer* being the most interconnected concept in the map with seven links, followed by *Intelligence assessments* (six links), *Different sources of information* and *Limited interaction* with five links each.

3.1.2.12 CMap 13: Intelligence cycle (*Figure 19*)

This map outlines a number of issues with the current model of intelligence cycle, such as exclusion of the actors, unidirectional flow, assumption of the information "pull" (as opposed to the information "push"), and omission of counter-intelligence. The map has links to an extensive collection of resources on the topic, including different versions of the model proposed in the literature and articles discussing its advantages and limitations. The map has a semi-hierarchical structure with its root concept – *Intelligence cycle* – being the most interconnected concept (eight links) followed by the concepts of *Criticisms of the original intelligence cycle model* (seven links). Each of the remaining concepts has three or fewer links.

3.1.2.13 CMap 14: Intelligence evaluation (*Figure 20*)

This map portrays the dichotomy of intelligence evaluation discussed in the literature (e.g., Tetlock and Mellers 2011) that contrasts the evaluation of intelligence products with evaluation of intelligence process. The map has a hierarchical structure with two branches coming out of the root concept – one is devoted to the *Evaluation of the intelligence product* and the other to the *Evaluation of the intelligence process*, which are the two most interconnected concepts in the map with four and five links respectively. The map could be further developed by including cross-links between the two branches, thus, identifying an overlap between the two approaches.

3.1.2.14 CMap 15: Intelligence organizations (*Figure 21*)

This map lists Canadian organizations that conduct intelligence analysis either as their main function or among their other activities. The map also includes Canadian professional organizations related to intelligence analysis, such as Canadian Association of Professional Intelligence Analysts, and Canadian Association for Security and Intelligence Studies. The map has a shallow and purely hierarchical structure with the concept *Organizations producing intelligence products* being the most interconnected with 11 links, and all other concepts with four links or fewer.

3.1.2.15 CMap 16: Intelligence products (*Figure 22*)

This map outlines some of the types of intelligence products that are produced by different organizations. Along with other pertinent concepts, two typologies of intelligence products are included in the map: one is based on the level of analysis required (tactical, operational, or strategic) and the other is based on types of intelligence products (providing basic, current, estimative, or warning intelligence). The map has a semi-hierarchical structure with its root concept, *Intelligence products*, being the most interconnected in the map with 11 links, followed by the concept *Different types of intelligence products* (nine links), and the concept *Covered time frame* (five links).

3.1.2.16 CMap 17: Intelligence requirements (*Figure 23*)

This map outlines some of the properties of intelligence requirements and the resulting issues that may affect the process of intelligence analysis. The map highlights the potential difference in interpretation of intelligence requirements by different stakeholders in the process (i.e., analyst, collector, manager, and consumer) and makes a note that intelligence consumers do not always provide input into the formulation of intelligence requirements. The map has a semi-hierarchical structure. The most interconnected concept of the map is *Intelligence requirements* with 11 links, followed by the concept *Intelligence consumer* and *Interpretation of requirements* with four links each.

3.1.2.17 CMap 18: Issues in information search and evaluation (*Figure 24*)

Information is one of the main resources analysts rely on in conducting intelligence assessments. Analysts have to search for information and identify relevant and reliable pieces that could be

used in their analysis. This map outlines some of the issues involved in information search and evaluation, such as analysts' expectations may affect their search and evaluation strategies, information classification level may affect perception of its importance, which, in turn, may affect its evaluation. The map has a network structure with a somewhat obscured root concept – *Information search*. The most interconnected concept of the map is the concept *Information elimination* with nine links, followed by the concept *Available information* with eight links, and the concepts *Access to information*, *Analyst's expectations*, *Information search*, and *Information sources* with five links each.

3.1.2.18 CMap 19: Main elements and processes in intelligence analysis (*Figure 25*)

This map captures various stages of information processing in intelligence analysis. It includes issues related to the potential variability in interpretation and understanding intelligence requirements that guide the information search, evaluation, processing, and analysis, and the resulting intelligence product, which is intended to benefit the intelligence consumer. The map has a network structure without a distinct root concept. The most interconnected concepts in the map are *Intelligence analyst* (seven links), *Intelligence manager* (seven links), *Analysis* (six links), *Information search* (six links), and *Collection of "raw" information* (five links).

3.1.2.19 CMap 20: Main players in intelligence analysis (*Figure 26*)

This map makes an emphasis on portraying different aspects of relationships among the players involved in the intelligence analysis process, namely intelligence analyst, manager, consumer, collector, and collator. The map has only five concepts, each representing one of the above mentioned roles, and 16 propositions that specify different aspects of interactions among the players. The map has a network structure, in which most pairs of concepts are connected with two or more propositions. The most interconnected concepts in the map are *Intelligence analyst* (ten links) and *Intelligence manager* (seven links), with the remaining concepts having four links each.

3.1.2.20 CMap 21: Management issues (*Figure 27*)

This map outlines some of the issues that intelligence managers face that are associated with assessing the quality of intelligence products, evaluating analysts' performance, operating with a limited budget, and managing consumers' needs and expectations. The map has a semi-hierarchical structure with the concept *Intelligence managers* being both the most interconnected (five links) and the root concept of the map. Other concepts in the map have three or fewer total links.

3.1.2.21 CMap 22: Managers' tasks (*Figure 28*)

This map outlines a number of tasks that intelligence managers perform, including, evaluation of products and individual performance, supervising analysts and ensuring their adequate professional development, managing resources, setting production expectations and outlook, and maintaining relationships with the IC. This map focuses on listing different tasks and

responsibilities of intelligence managers, while CMap 21 focuses on outlining some of the difficulties that managers experience in carrying out their tasks. CMap 22 has a semi-hierarchical structure with the two most interconnected concepts being *Intelligence manager* (eleven links) and *Intelligence analyst* (eight links). All remaining concepts have five links or fewer.

3.1.2.22 CMap 23: Purpose of intelligence analysis (*Figure 29*)

This map conceptualises the main purpose of intelligence analysis as: *to satisfy the intelligence need and to improve intelligence consumer's understanding*. The map also captures the idea that different intelligence needs are best addressed with different types of intelligence products. The idea of intelligence need is central in this map, and the concept *Intelligence need* is the most interconnected concept (seven links), although it is not the root concept.

3.1.3 Organization of the KM

The CMaps in the model are organized and interlinked in a semi-hierarchical fashion. As a result, different maps in the model have varying levels of detail with some maps being more general and other maps being more detailed. Each CMap of the model aims to identify concepts that are central to the topic of the map, and these concepts are disambiguated through their relationships among each other.

The top-level map on intelligence analysis (CMap 10, *Figure 16*) is the entry point into the model. This map's focus question is fairly broad – "What is intelligence analysis?" – and this map provides a general overview of the topics included in the model, e.g., intelligence products, intelligence cycle, application of analytic tools, cognitive issues, and players in the intelligence analysis process. The top-level map has links to all other maps of the model.

With a few exceptions, almost all of the concepts in the top-level map link to a separate map on that topic or a topic (or topics) related to the concept. For example, the concept *Intelligence products* in the top-level map links to a CMap that discusses intelligence products in more detail (CMap #16, *Figure 22*). In addition, the concept *Intelligence products* links to two other CMaps, which discuss assessment difficulty (CMaps 5 and 6, *Figure 11* and *Figure 12*). Similarly, the concept *Application of analytic tools* links to the CMap discussing analytic tools (CMap 4, *Figure 10*). All CMaps that are linked to a given concept in a map are grouped under the CMap icon attached at the bottom of the concept box (for more details on technical aspects of navigating through the model see Sub-section **3.2.2**).

From the top-level map, the user can go one level down in the KM, and open, for example, a CMap on analytic tools (CMap 4, *Figure 10*) from the concept *Application of analytic tools*. As the name suggests, the map on analytic tools provides more detailed information about analytic tools. This map, although it may not seem very extensive, contains a substantial quantity of information. On the left side of the map, there is a section addressing the general purpose of analytic tools; and factors that influence the application of analytic tools are included on the right side of the map. The concept *Cognitive and social biases* on the left side of the map has a link to the map on cognitive issues in intelligence analysis (CMap 7, *Figure 13*) and the concept *Information overload* has a link to the map on issues in information search and evaluation (CMap 18, *Figure 24*). A number of analytic techniques discussed in the Aide Memoire on Intelligence

Analysis Tradecraft (Thompson 2009) is shown in the middle section of the map. Following the organization of the Aide Memoire, all of the techniques are grouped into three functional application areas. Each technique is put into a single node, which has a link to the technique's description from the Aide Memoire. Some of the techniques also have other resources attached, such as descriptions from other sources (e.g., CIA Primer 2009), a link to a website for downloading the software for the tool (e.g., for the ACH), or a more detailed CMap on the tool (e.g., map on ACH, CMap 1, *Figure 7*). The CMap on ACH, provides the next level of detail in the KM, and links back to the CMap on analytic tools. Eventually, the KM will have a detailed CMap for each of the analytic techniques. As a result, the CMap on analytic tools also links back to the top-level CMap on intelligence analysis, and thus provides an easy access to all relevant available information in the model.

Other maps in the model follow similar organization and include links to more detailed or more general maps on relevant topics. In addition to linking to other related maps, each map in the model has a link to the top-level map, which facilitates navigation within the hierarchy of topics. In addition to providing a conceptual representation of various topics relevant to intelligence analysis, the model also serves as a resource depository by linking concepts to other types of material, which can be referenced from different locations. Organizing one's knowledge in the CMap KM form allows representing knowledge at different levels of detail with an easy access to relevant maps (more detailed or more general). Such organization facilitates awareness (in both the model creator and a model reader) of how different topics interrelate and how they contribute to the bigger picture.

3.1.4 Potential applications of the model and its components

We have envisioned two potential applications of the CMap KM of intelligence analysis within the IC:

- to foster conceptual development in the area of intelligence analysis, and
- to assist in the training of intelligence analysts.

We discuss these two potential applications of the model in more detail below.

3.1.4.1 Conceptual development within the IC

Despite its wide practice, intelligence analysis has a relatively sparse body of unclassified academic and practitioner literature that concentrates on developing theoretical and conceptual issues relevant to intelligence analysis. Within the IC, there is a certain degree of subjectivity with respect to defining central concepts (such as *analytic rigour* and *analytic integrity*) and defining good analytic principles and practices (Bruce and George 2008). Several driving forces (such as recent intelligence failures of Canada's allies, greater public attention and demand for increased accountability) have been steering towards the development of a discipline of intelligence analysis with systematic procedures for archiving, retaining, and accessing the collective knowledge and wisdom of its practitioners, and well defined analytic principles and practices (Fisher and Johnston 2008).

A conceptual model of intelligence analysis, such as the present CMap KM, may serve as a springboard for discussion and collaboration within the IC in order to identify and define relevant concepts and develop shared understanding. The CMap mode of representation allows concepts and their relationships to be represented in a concise and graphical form. In addition, CMaps could be particularly helpful in revealing differences in current understanding of a topic among individuals (Hay 2007, Hay and Kinchin 2008, Novak 1998), which could be especially useful at the early stage of the development of conceptual ideas.

A CMap KM of intelligence analysis can be stored in a shared server location, which will provide easy access to its content via the Internet. Intelligence professionals would be able to review the content, comment on it, add resources, and make modifications to the existing maps and create new ones.

3.1.4.2 Training of intelligence analysts

The CMap KM of intelligence analysis can also be adopted for training purposes as a form of an advanced organizer of the material and as a resource management system. The model can be modified to reflect the current curriculum of the intelligence analysis training program, such as the entry-level intelligence analysis training course offered through the Privy Council Office's Intelligence Assessment Learning Program, or the entry-level course at the Canadian Forces School of Military Intelligence. Such a model can serve several different purposes:

- The model can provide intelligence analyst trainees with an overview of the training program curriculum and demonstrate how different topics and training modules relate to one another;
- Similarly, the model can provide the course instructors with an overview of the entire curriculum in a visual and organized fashion, which can help them to structure the material and identify potential gaps in the concepts covered;
- Through the ability of CMaps to make explicit differences in conceptual understanding, the model can encourage conceptual discussions among trainees and instructors, and, ultimately, facilitate conceptual understanding among the trainees and conceptual development in the area of intelligence analysis in general;
- The model can serve as resource depository, providing easy access to relevant course material, which trainees can retain after completing the course and use it as a reference resource. In addition, the model can help in identifying gaps in resources.

3.2 Technical description of the model

3.2.1 CMaps and resources included in the model

The CMap KM currently consists of 23 interlinked CMaps on various topics pertinent to the intelligence analysis process. *Table 1* provides a list of the CMaps that are currently included in the model, indicating for each map its topic, root concept, focus question, number of concepts in the map, number of propositions, and number of links to various resources. The maps in the

model are interlinked through the "Resources" capability of CMapTools. *Table 2* shows cross reference among the CMaps in the model. The "X" symbol appears in those cells of *Table 2* in which the row map has a link to the column map. The last column of *Table 2* shows the total number of CMaps that a given CMap links to, and the last row shows the number of other maps that link to a given CMap. All CMaps currently included in the model are presented in **Annex A**, *Figures 7 – 29*. The CMaps' numbers used in *Table 2* and in *Figures 7 – 29* correspond to those of *Table 1*. *Table 3*: lists the number of resources of different types used in the model.

3.2.2 Access to the model in electronic form

The model is available in electronic form in both CMapTools and web page formats and can be obtained on a compact disk (CD) from the first author[2]. Currently, the model can be downloaded from the DRDC Toronto internal network, and the authors are exploring options available for making the model available for download from outside DRDC Toronto.

The model files are stored on the DRDC Toronto's internal network in the following folder:

\\Pluto\public\Concept Map Knowledge Model of Intelligence Analysis\

The CMapTools version of the model is compressed into a zip file with the name "*CMap KM of Intelligence analysis CMapTools version.zip*", which can be downloaded from the above folder. The CMapTools version of the model cannot be browsed on the server as it currently does not have a CMapTools server installed. The model needs to be downloaded, unpacked, and opened with the CMapTools software installed on the user's computer. CMapTools software is required for opening the model in the CMapTools format.

The web page version of the model can be browsed directly from the server, and it can be accessed by opening the file "*CMap KM of Intelligence Analysis web page version.html*" located in the aforementioned folder. Browsing the model in the web page format requires that Java scripting is enabled in the browser.

3.2.3 Navigation through the model

Navigation among the maps in the model is implemented through the resources feature of CMapTools software, which allows attaching different types of resources to concepts and links in a CMap. The resources are grouped according to their type under different resource icons that are attached at the bottom of a concept or a linking phrase. All CMaps attached to a given concept are grouped under the CMap resource icon. To navigate to a different map, the user clicks on the map icon and chooses a map from the list. Different resources including maps could be cross-referenced from different places.

[2] Natalia Derbentseva can be reached via e-mail at Natalia.Derbentseva@drdc.rddc.gc.ca

Table 2: Cross-reference among the CMaps in the KM

Map #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Links OUT
1				X						X														2
2			X							X						X								3
3	X	X		X		X	X			X		X			X	X			X	X	X	X		13
4	X						X			X								X						4
5		X				X				X								X						4
6		X		X	X					X								X						5
7	X			X						X								X						4
8		X	X				X			X	X	X		X			X	X	X	X	X	X		13
9	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	22
10	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	22
11		X	X				X			X		X					X	X			X	X		9
12		X	X				X			X				X		X	X	X						8
13			X							X	X	X					X		X	X		X		8
14				X						X		X					X				X	X	X	7
15										X														1
16		X	X		X		X			X		X			X		X				X	X	X	11
17		X	X				X			X	X	X				X		X			X	X		10
18		X	X				X			X	X													5
19		X	X	X	X		X		X	X	X	X		X		X	X	X			X	X	X	16
20		X	X				X	X		X	X	X						X			X	X		10
21		X	X		X		X		X	X		X		X		X						X		10
22		X	X			X	X	X	X	X		X		X	X	X	X		X		X		X	15
23		X	X				X			X	X	X				X	X	X	X	X	X	X		13
Links IN	5	16	15	8	6	5	15	4	4	22	9	14	2	7	5	10	11	13	7	6	12	13	6	

Table 3: Resources used in the CMap KM of intelligence analysis by type

Type of resource	Number of files included in the model
PDF and MS Word text files	76
Images	35
Internet URLs	16
CMaps	24
Audio	1

4 Conclusion

The field of knowledge concerning intelligence analysis and its practices is neither abundant nor well-organized. Practitioners of intelligence analysis view their profession predominantly as an "art" that lacks a set of agreed upon best practices and clear evaluation criteria. The development of concepts central to intelligence analysis has only recently started to emerge and a thorough theoretical understanding of issues pertinent to this activity is still lacking (Bruce and George 2008, Johnston 2005, Marrin and Clemente 2006).

In the context of an ARP project aimed at understanding and augmenting human capabilities in intelligence production, we have reviewed available unclassified academic and practitioner literature on intelligence analysis and have engaged in ongoing interactions with intelligence professionals in order to gain an understanding of the intelligence analysis process and to identify existing issues and areas for further social and cognitive science research and development. The CMap KM of intelligence analysis and this technical report are two outcomes of that endeavour. The CMap KM focuses on the human aspect of intelligence analysis and has a relatively wide coverage of topics relevant to intelligence analysis in the following three areas:

- The individual actors involved in the intelligence analysis process,
- The environmental requirements and constraints that impact intelligence analysts, and
- The process of analysis.

In addition, the model serves as a resource depository providing easy access to a range of relevant material.

To capture the content represented in the model, we could have used other, and, perhaps, more conventional, representational forms, such as a report or a book. However, we chose CMapping for a number of reasons. Firstly, a CMap offers an efficient way of navigating through a large amount of information and its representational form because:

- It is concise and relies on visual cues, which reduces the amount of information required to convey or absorb an idea;
- It affords a non-linear navigation both within a single map and among the maps of the model and is more interactive; and
- It allows the inclusion of numerous resources that can be accessed with a click of a computer mouse, which is not possible with more conventional representational forms

Secondly, the CMap KM of intelligence analysis introduces the IC to a novel form of knowledge representation in a relevant context, which may assist in the IC's evaluation of benefits and drawbacks of CMapping as a representational form. Thirdly, the KM showcases DRDC's capability to support knowledge representation activities and has already resulted in collaboration between DRDC and the Canadian IC. Such collaboration strengthens the relationship between DRDC and the IC and creates opportunities for further DRDC – IC partnership. The primary focus of the Canadian IC is on current operational needs, and resources available to further theoretical development in the area are scarce. DRDC possesses expertise in the area of

knowledge representation, and is therefore well-positioned to support and assist the IC in its efforts.

The CMap KM can be seen as a meta-overview of the area of intelligence analysis. Engaging in the development of such overall summaries for an area has a benefit to the community of practice: It can help in achieving conceptual clarity, contribute to the development of shared understanding within the community and provide a theoretical development of the area. It is our aspiration for this CMap KM that it might facilitate further conceptual development in the area of intelligence analysis by serving as a springboard for discussion within the IC.

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Annex A CMaps of the CMap KM of Intelligence Analysis

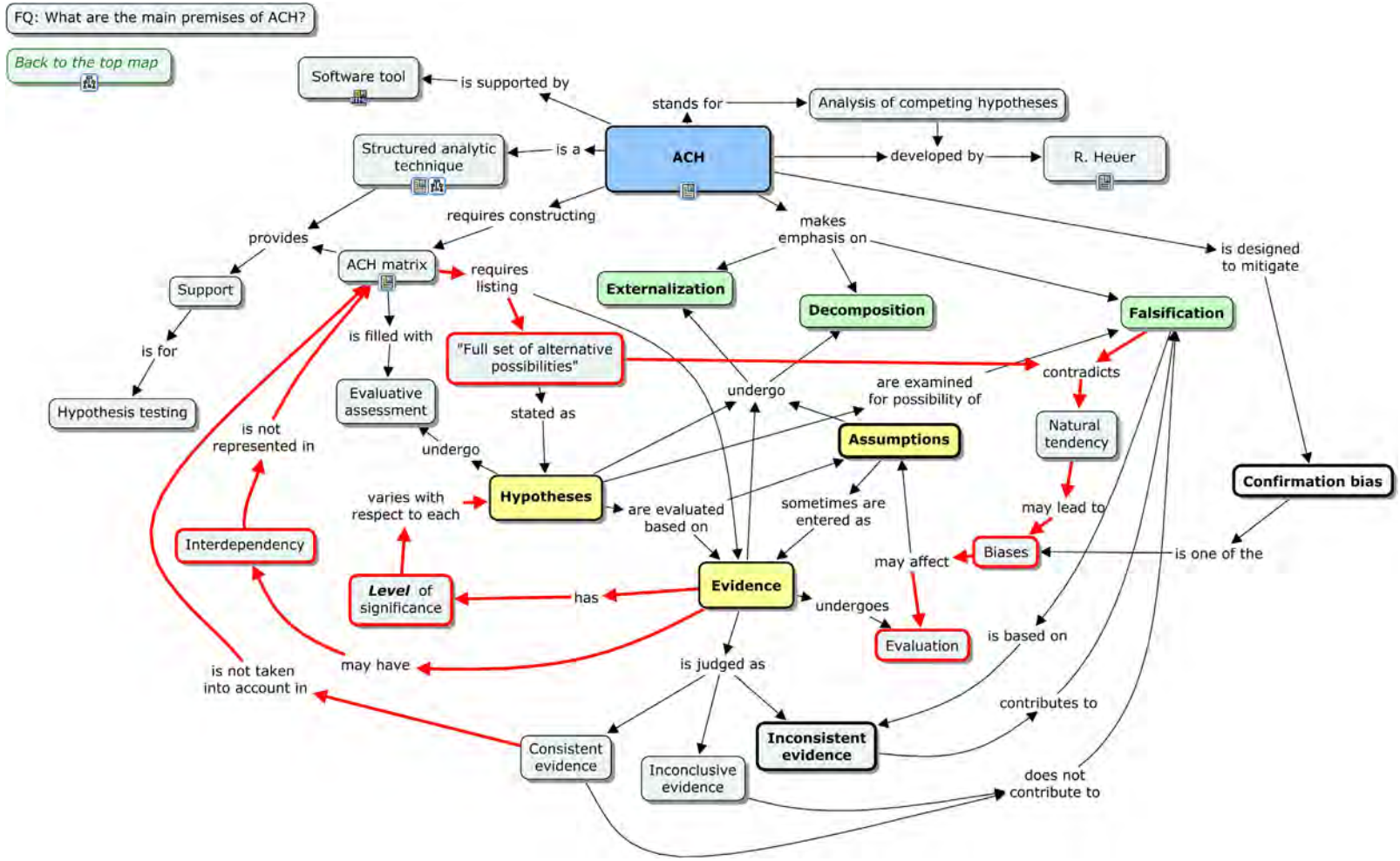

Figure 7: CMap #1: ACH. Focus Question: What are the main premises of ACH?

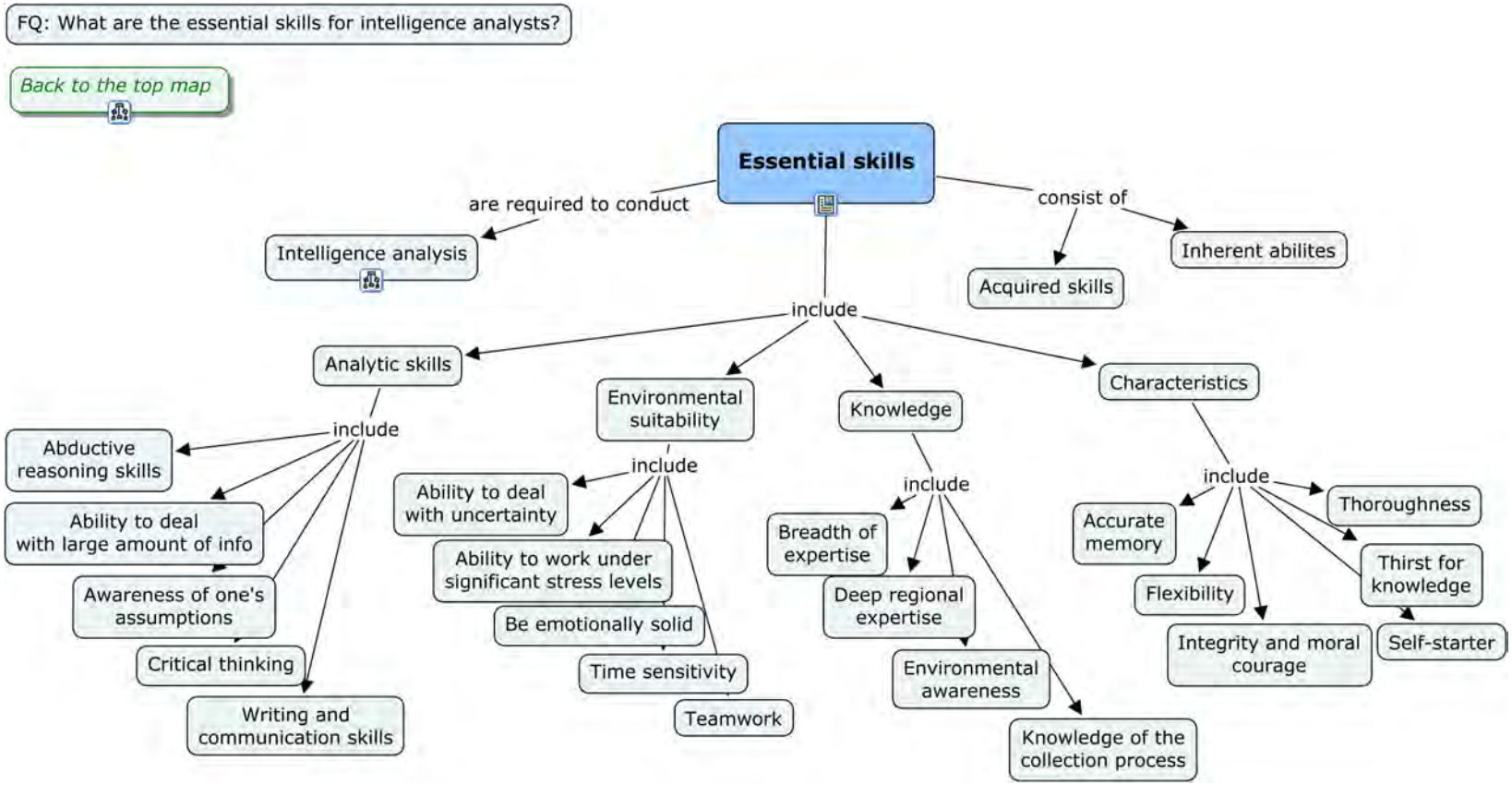

Figure 8: CMap #2: Analysts' skills. Focus Question: What are the essential skills for intelligence analysts?

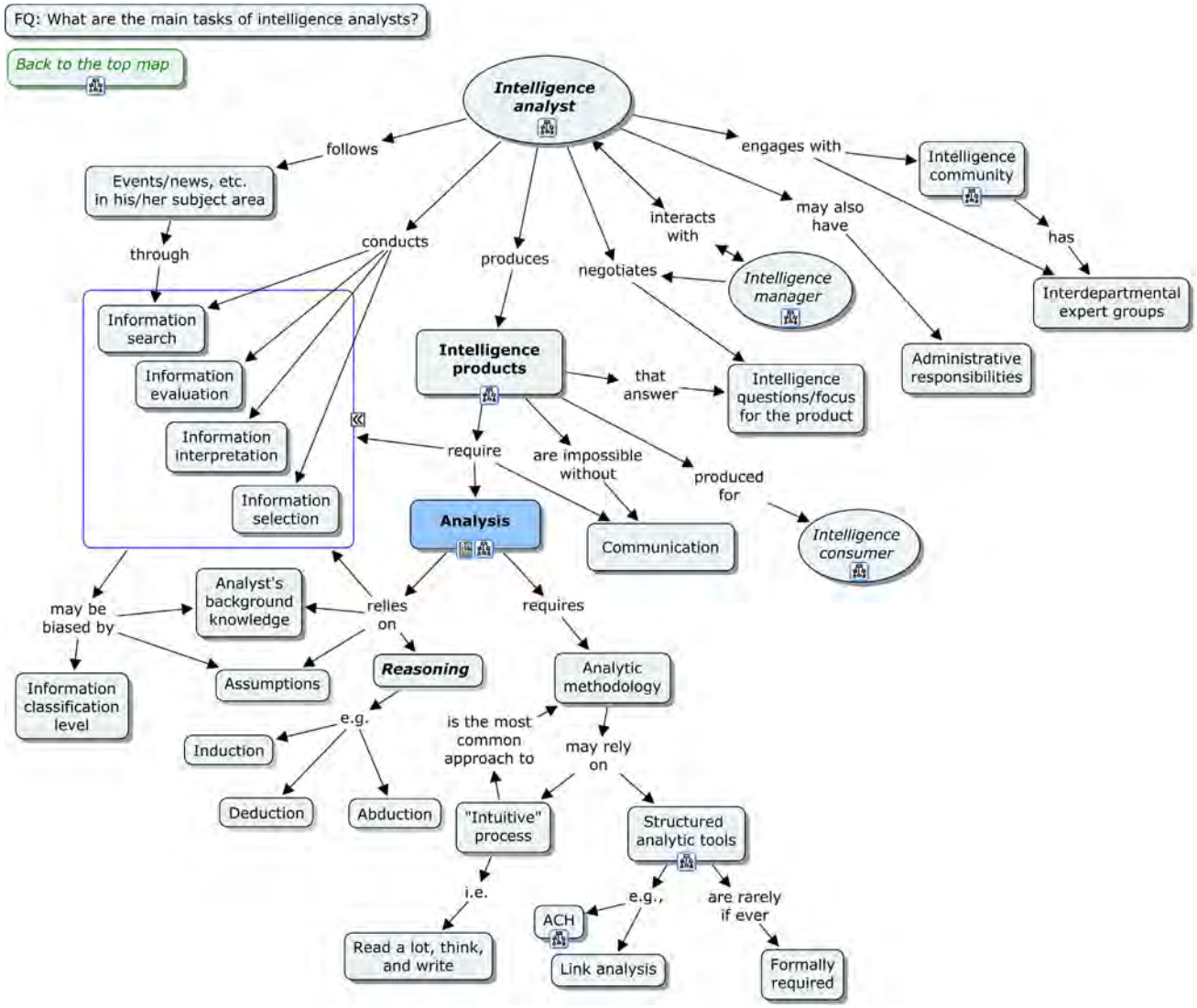

Figure 9: CMap #3: Analysts' tasks. Focus Question: What are the main tasks of intelligence analysts?

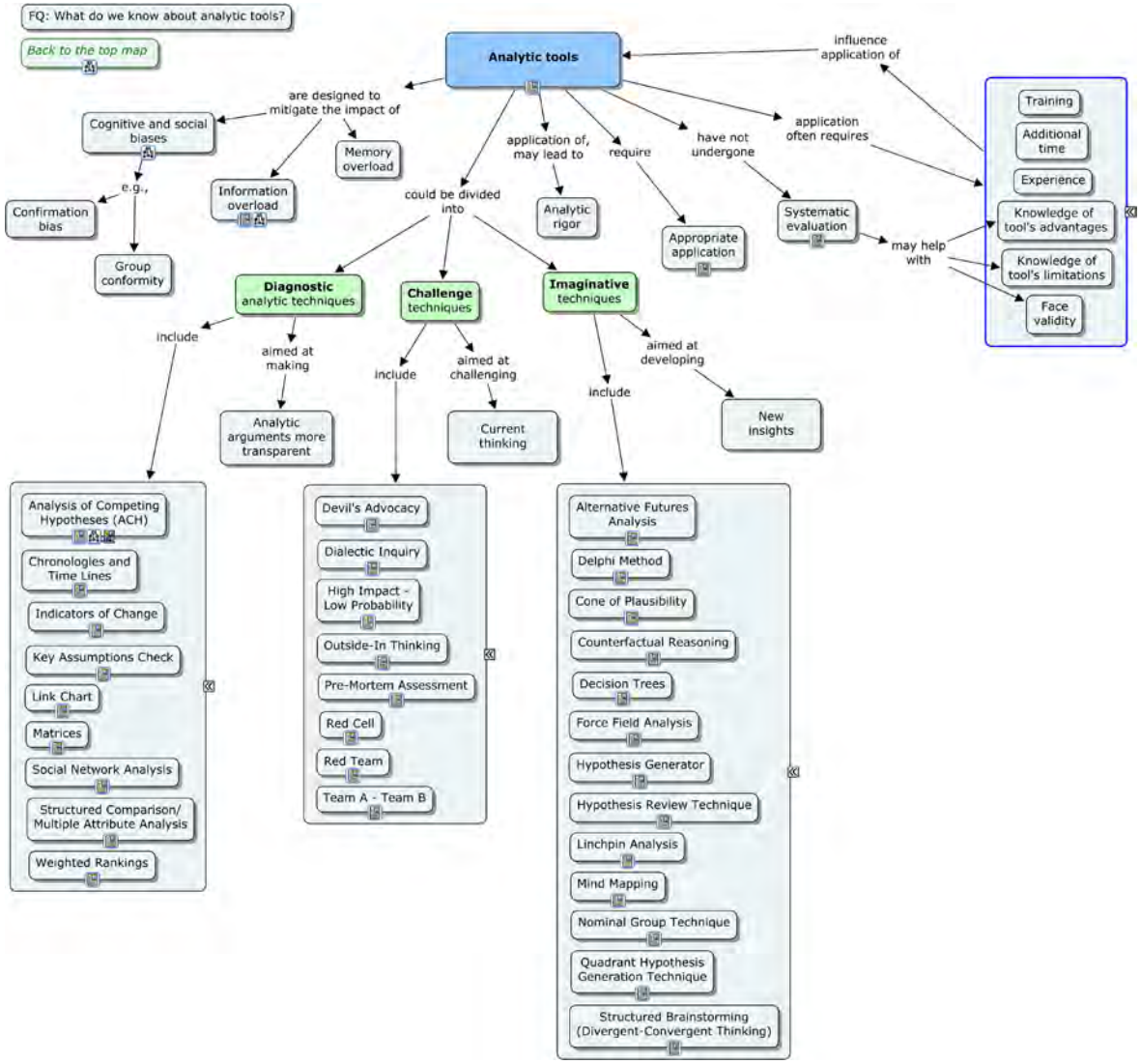

Figure 10: CMap#4. Focus Question: What do we know about analytic tools?

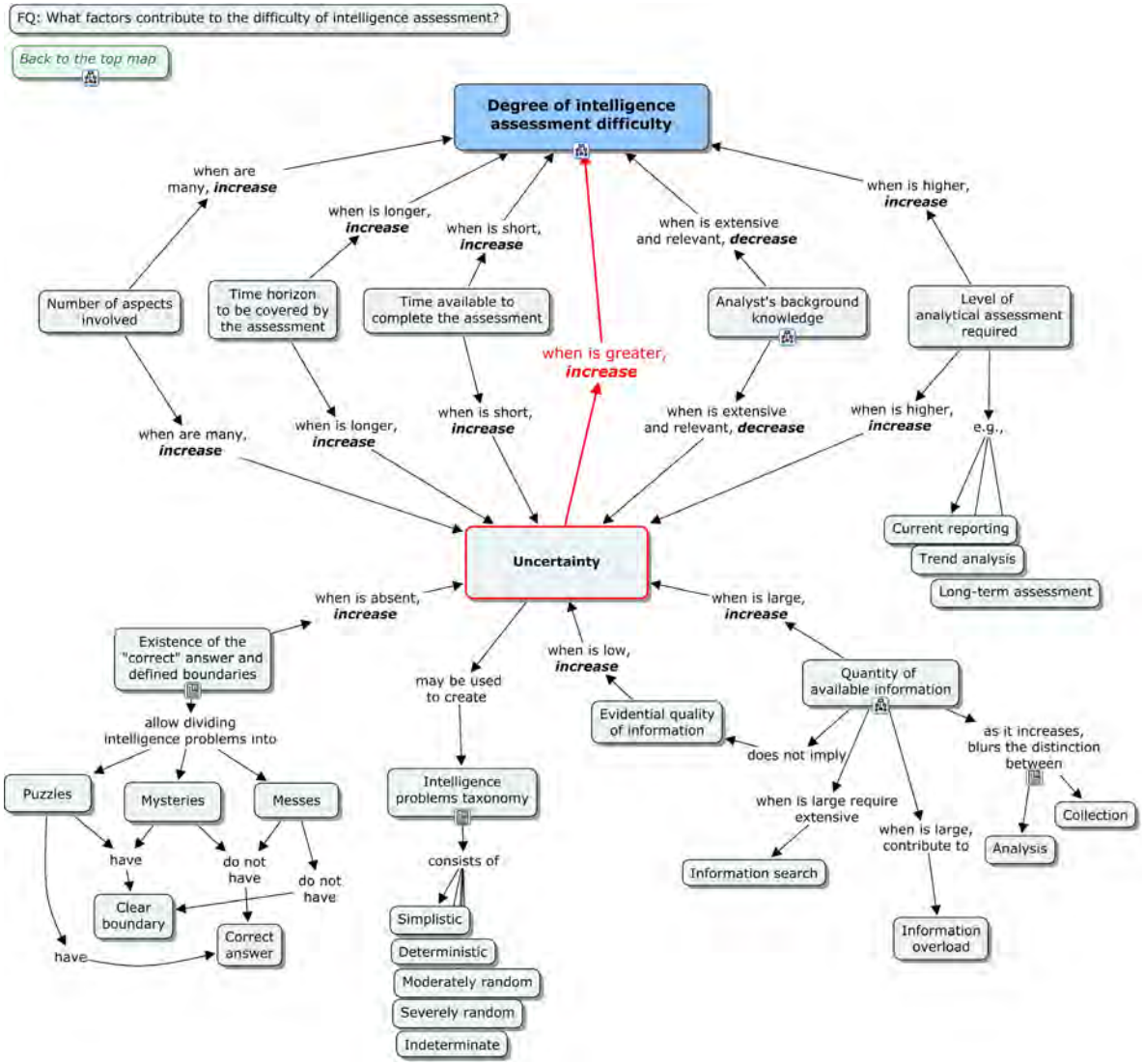

Figure 11: CMap #5: Assessment difficulty. Focus Question: What factors contribute to the difficulty of intelligence assessment?

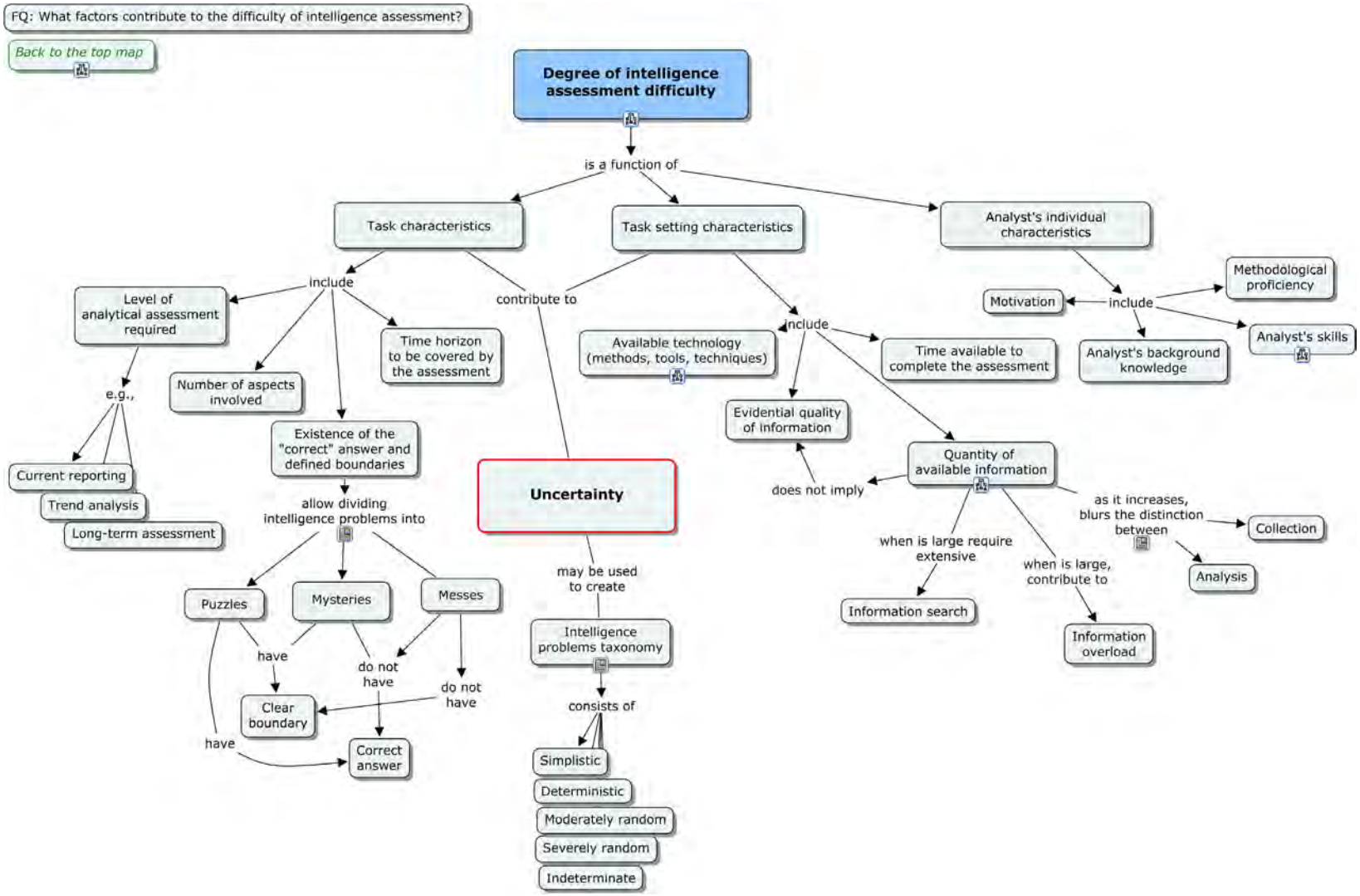

Figure 12: CMap #6: Assessment difficulty (tree). Focus Question: What factors contribute to the difficulty of intelligence assessment?

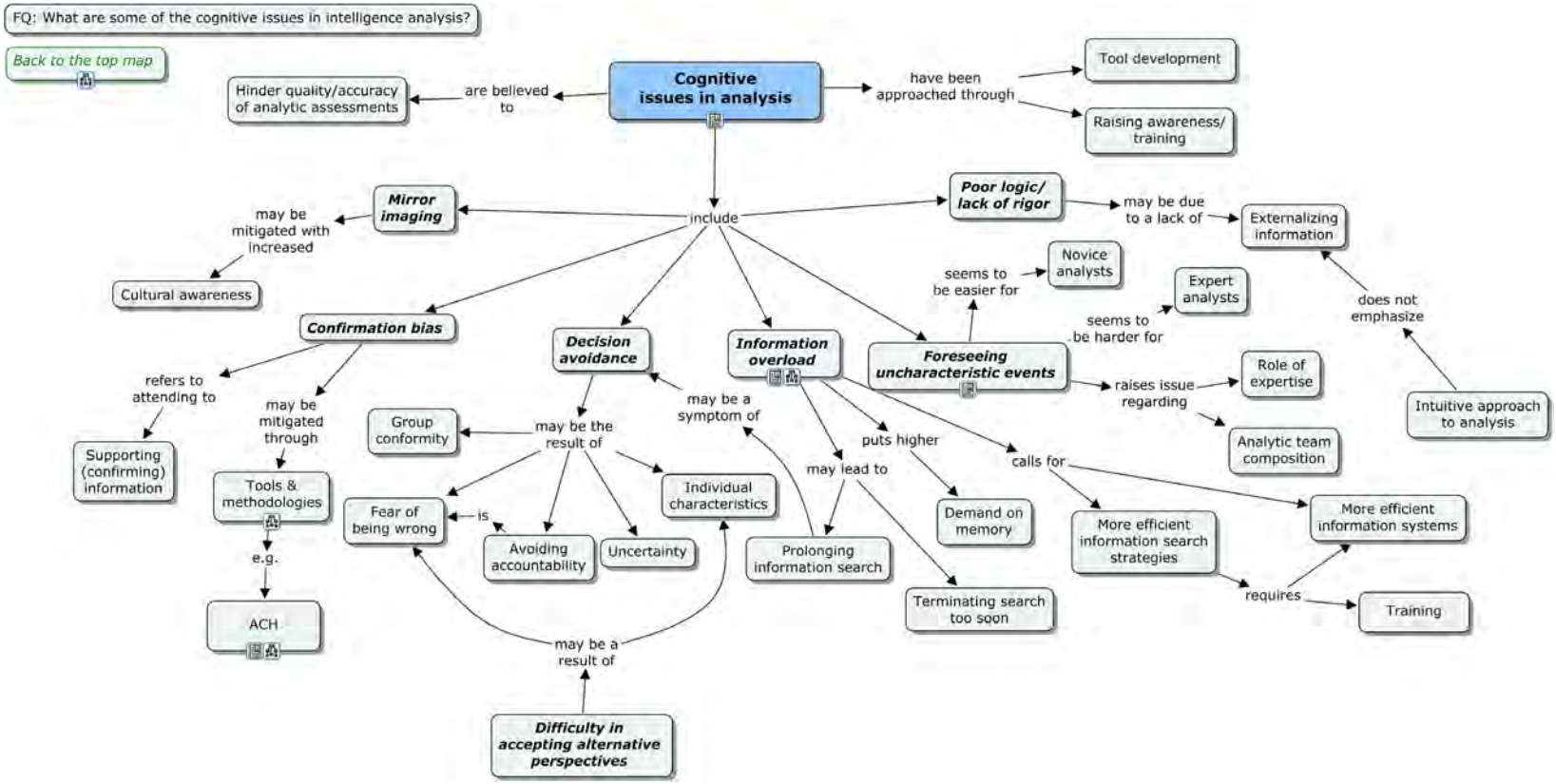

Figure 13: CMap #7: Cognitive issues in analysis. Focus Question: What are some of the cognitive issues in intelligence analysis?

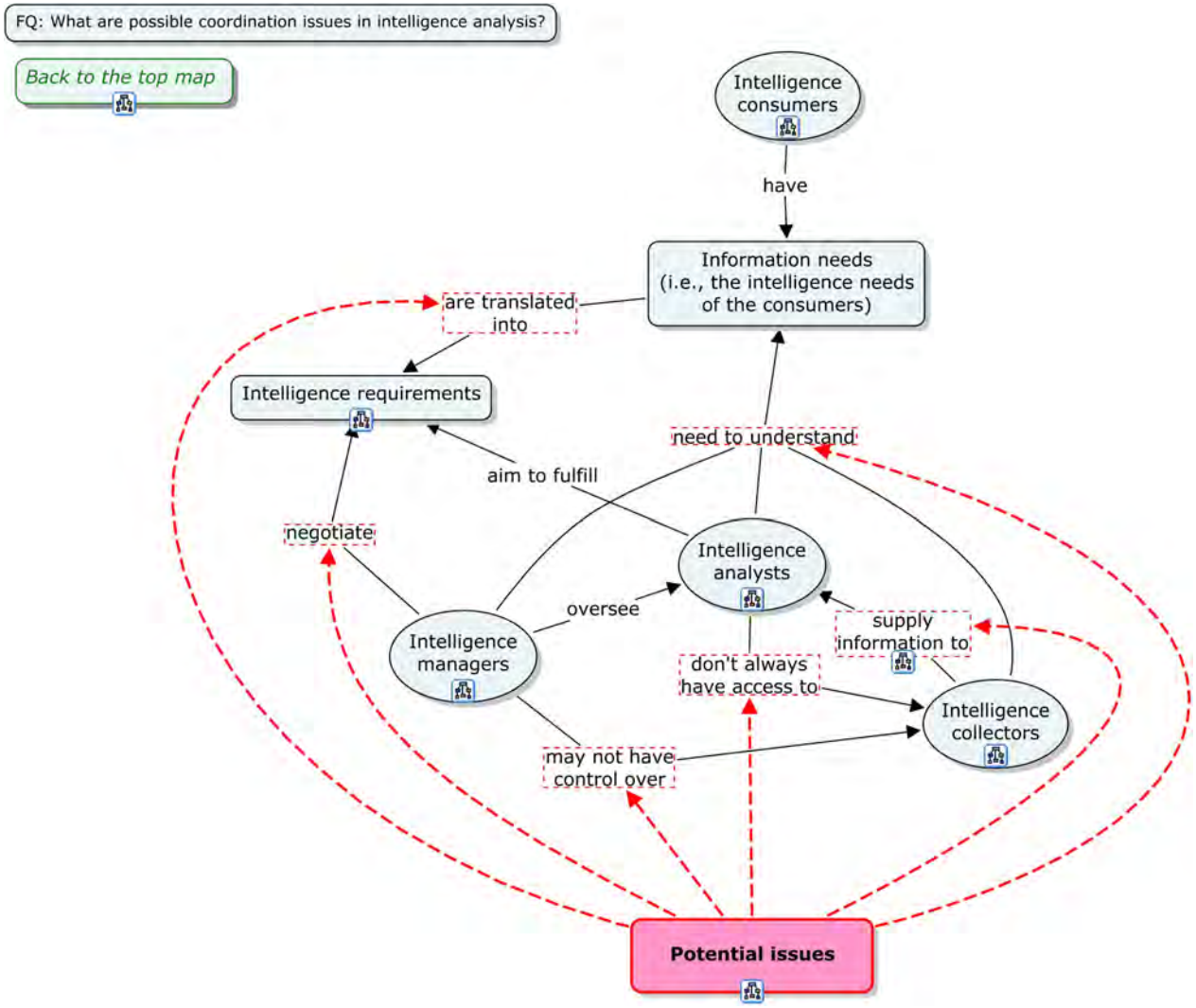

Figure 14: CMap #8: Coordination issues in the intelligence process. Focus Question: What are possible coordination issues in intelligence analysis?

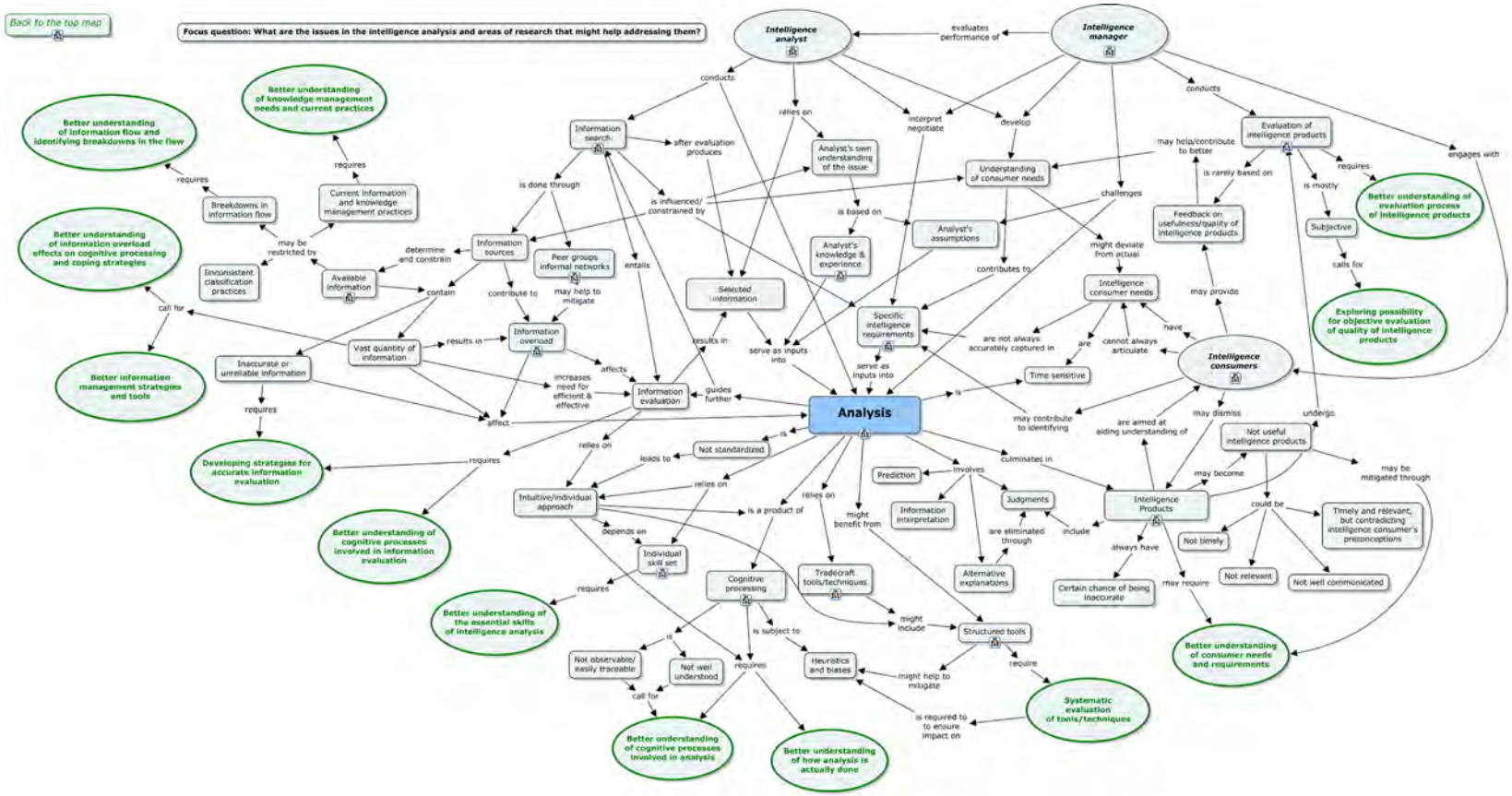

Figure 15: CMap#9: Intelligence analysis (large map). Focus Question: What are the issues in the intelligence analysis and areas of research that might help addressing them?

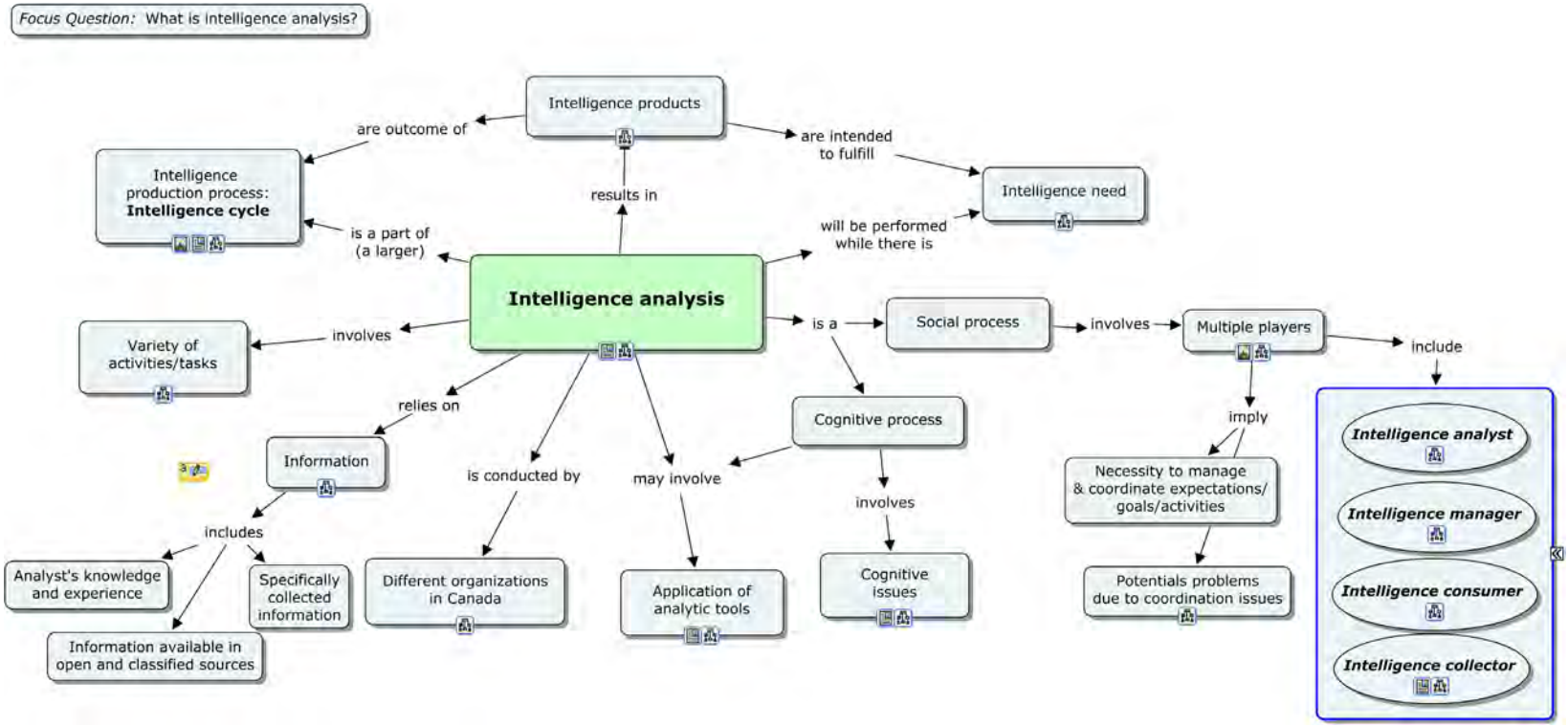

Figure 16: CMap #10: Intelligence analysis (Top Map). Focus Question: What is intelligence analysis?

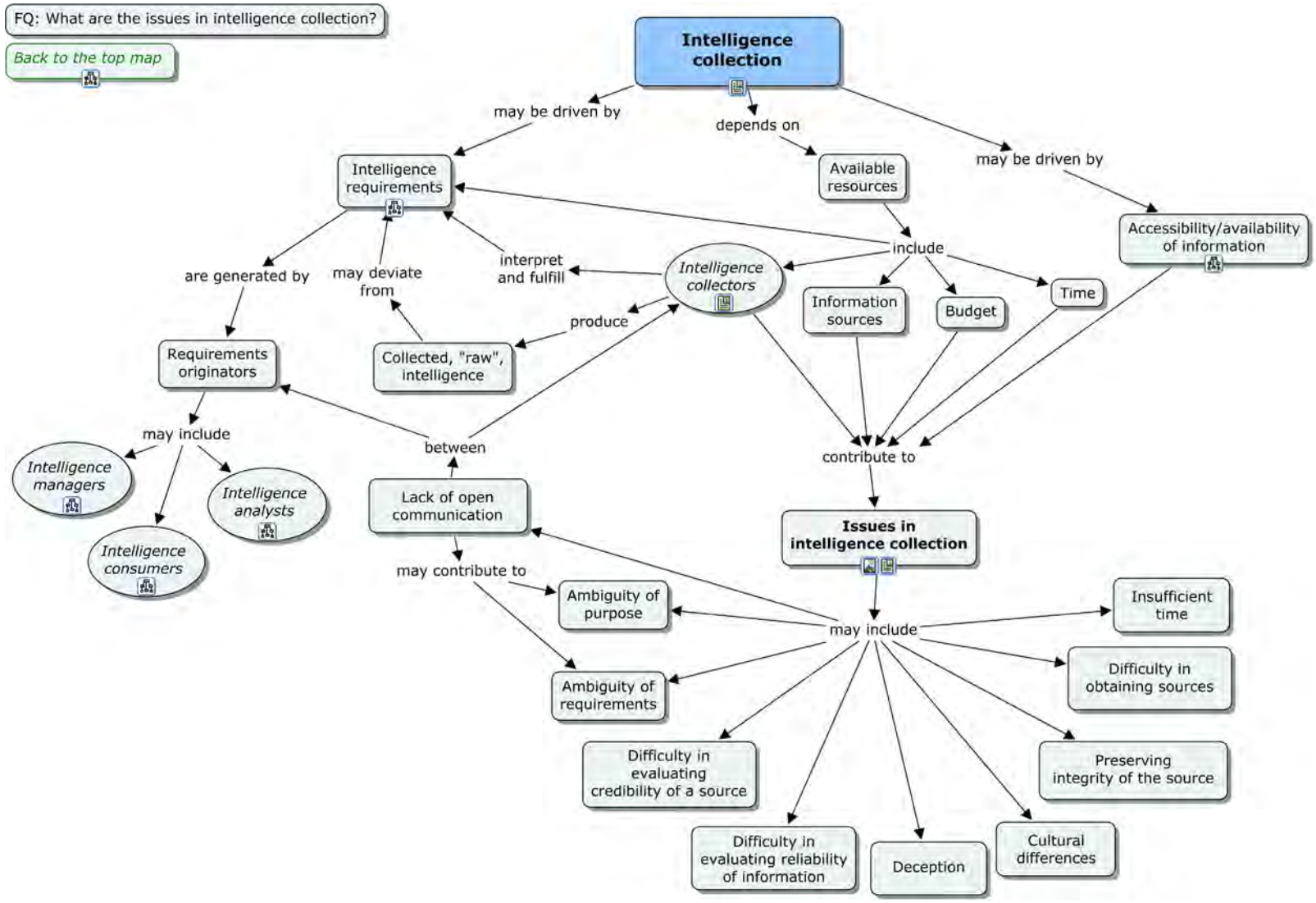

Figure 17: CMap #11: Intelligence collection. Focus Question: What are the issues in intelligence collection?

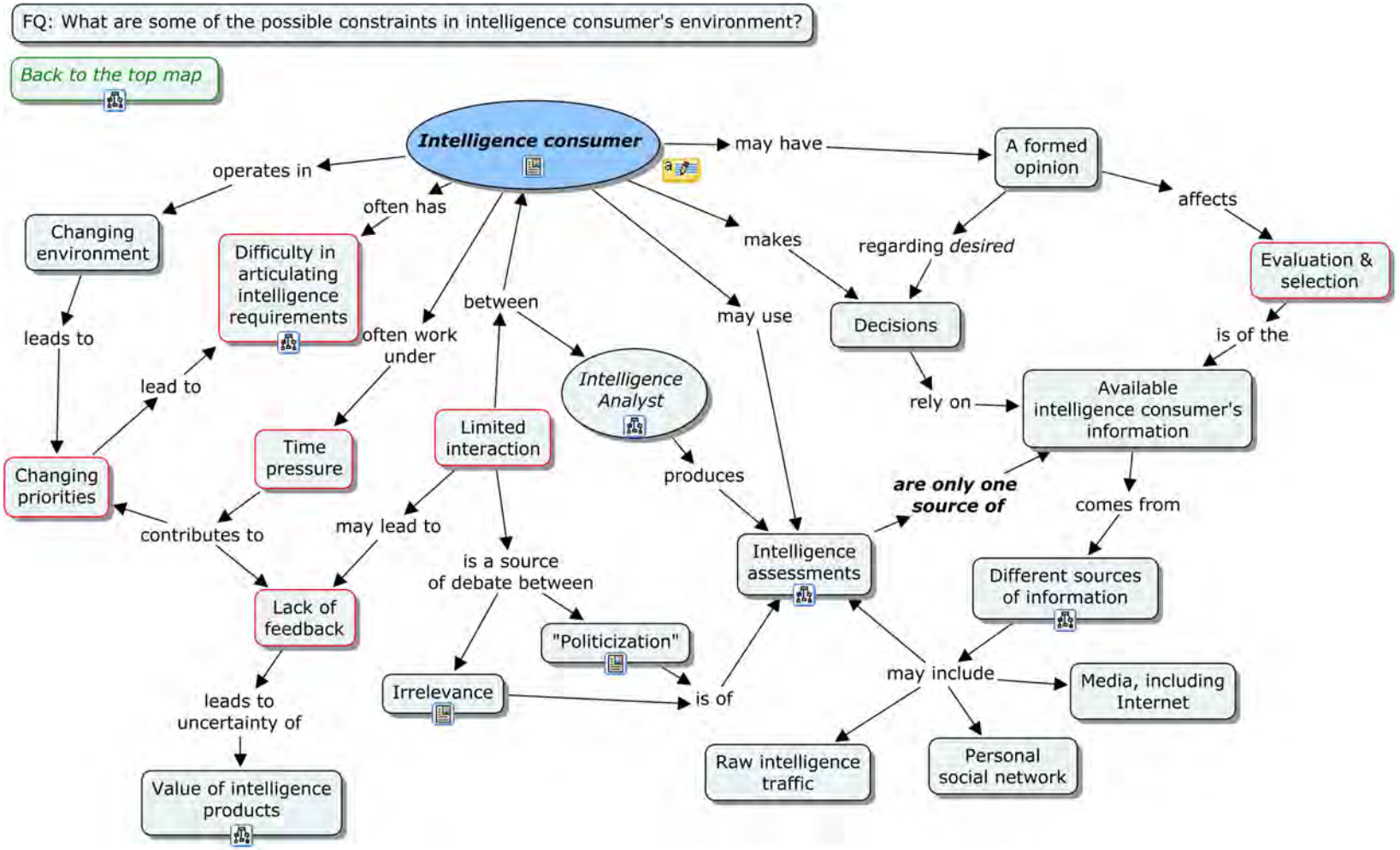

Figure 18: CMap #12: Intelligence consumer. Focus Question: What are some of the possible constraints in intelligence consumer's environment?

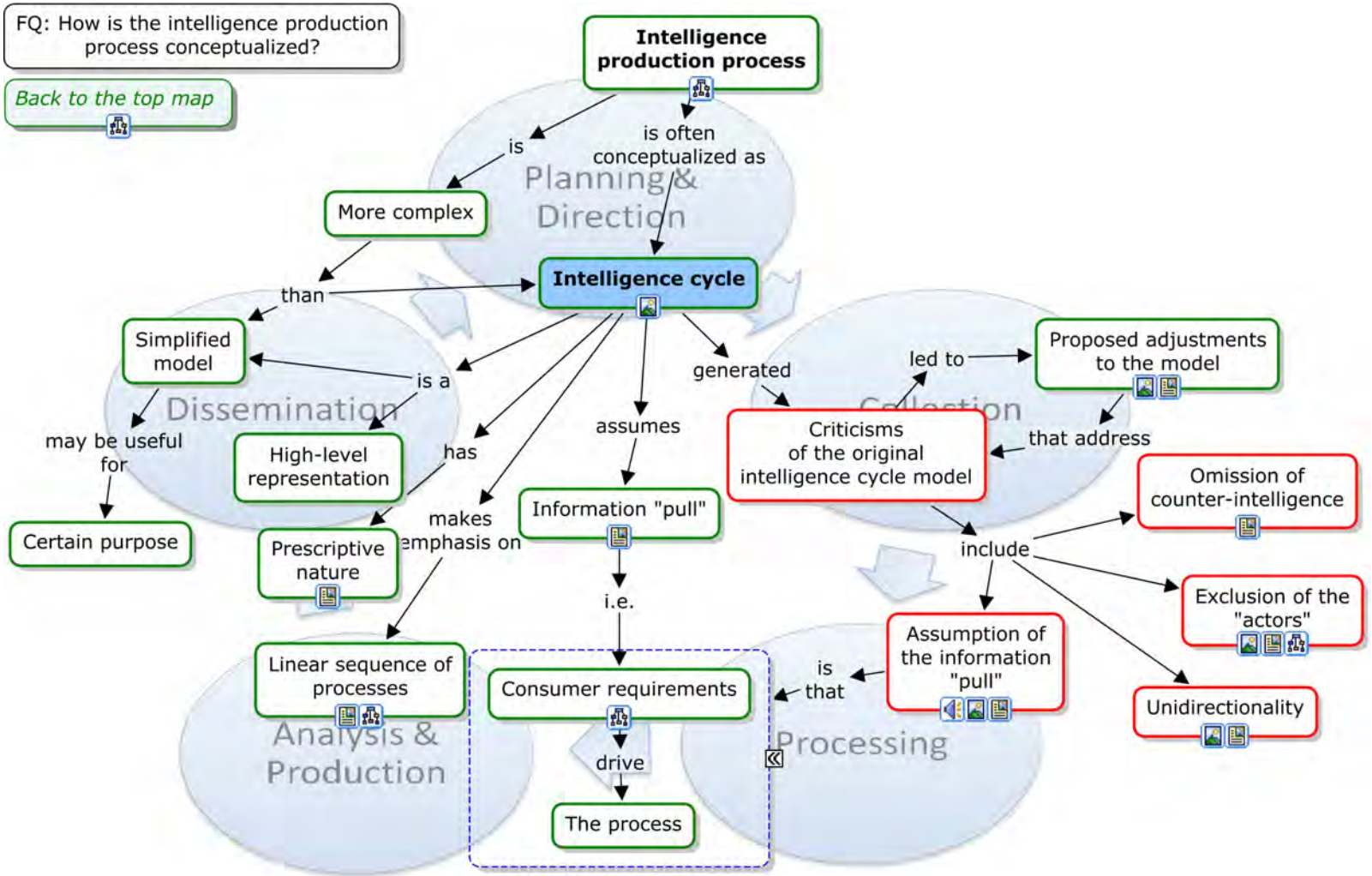

Figure 19: CMap #13: Intelligence cycle. Focus question: How is the intelligence production process conceptualized?

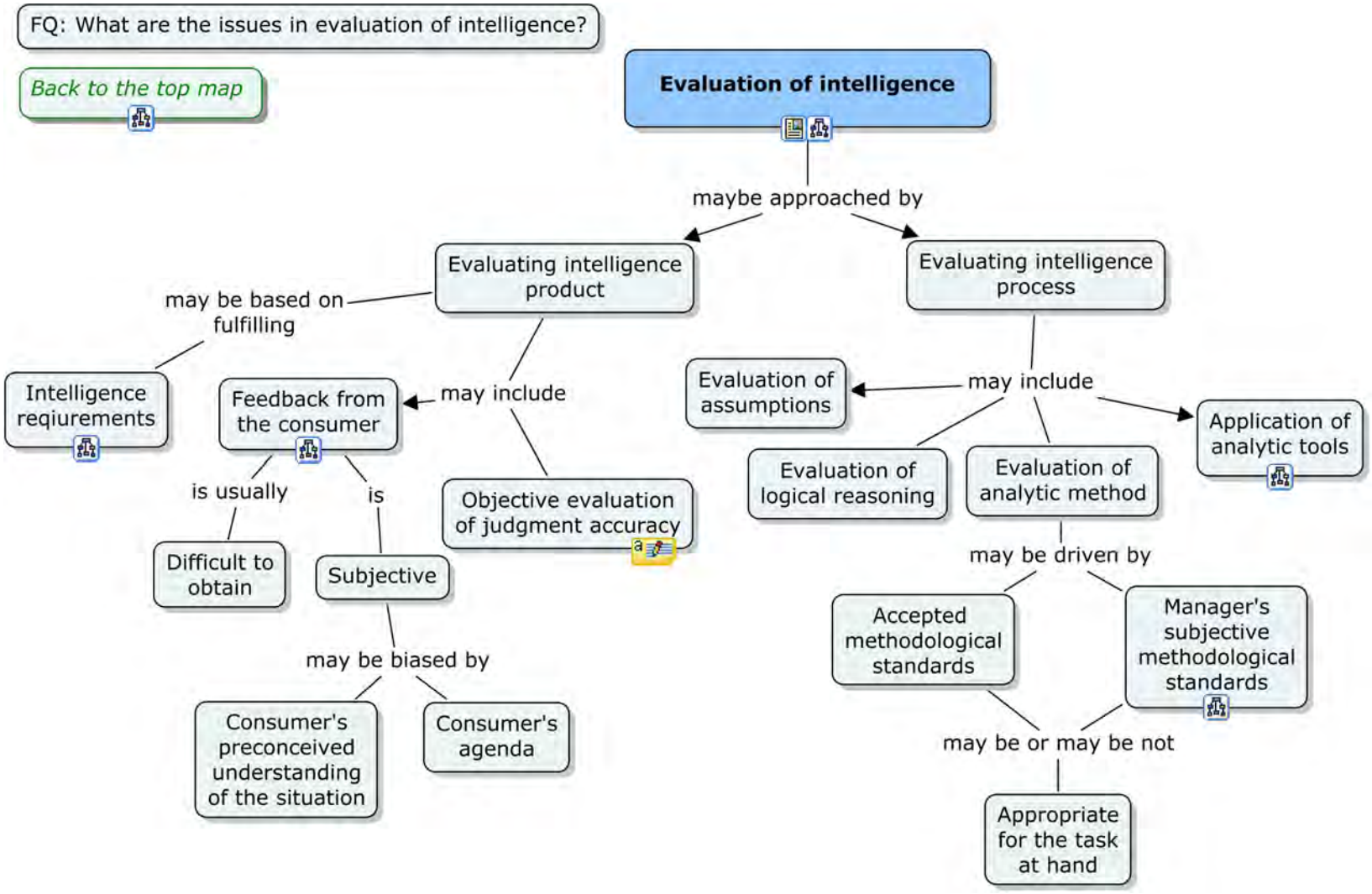

Figure 20: CMap #14: Intelligence evaluation. Focus Question: What are the issues in evaluation of intelligence?

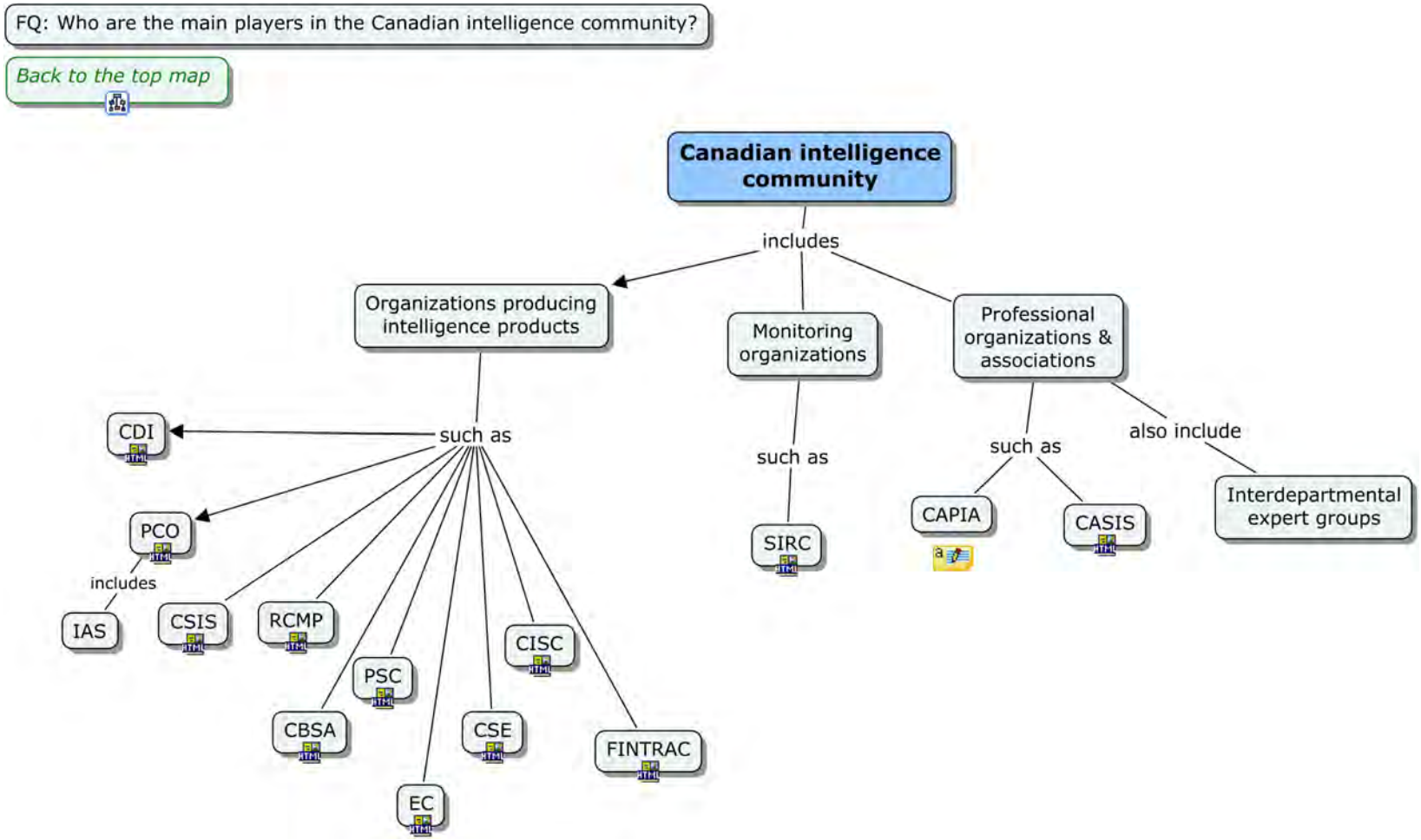

Figure 21: CMap #15: Intelligence organizations. Focus Question: Who are the main players in the Canadian intelligence community?

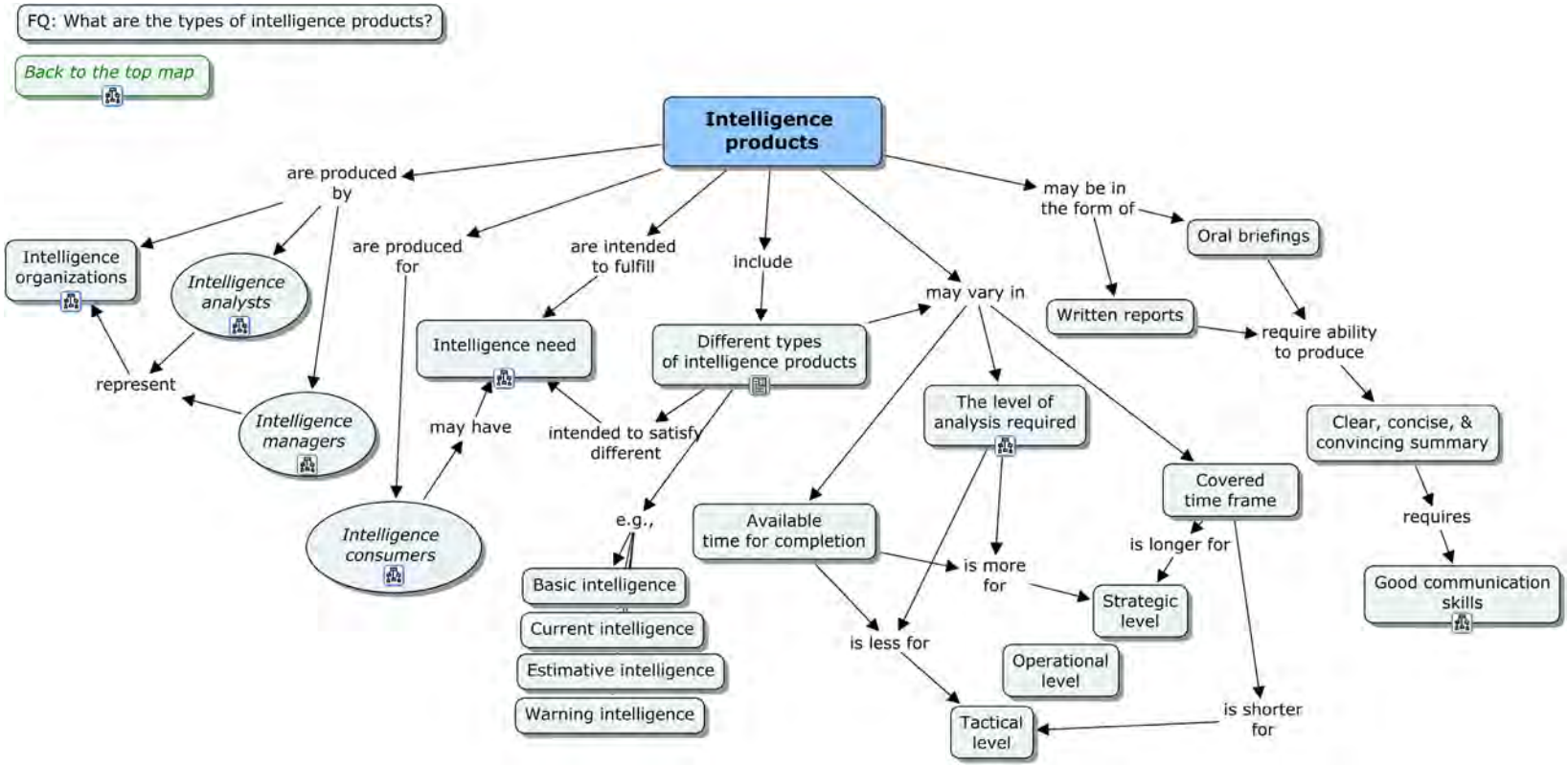

Figure 22: CMap #16: Intelligence products. Focus Question: What are the types of intelligence products?

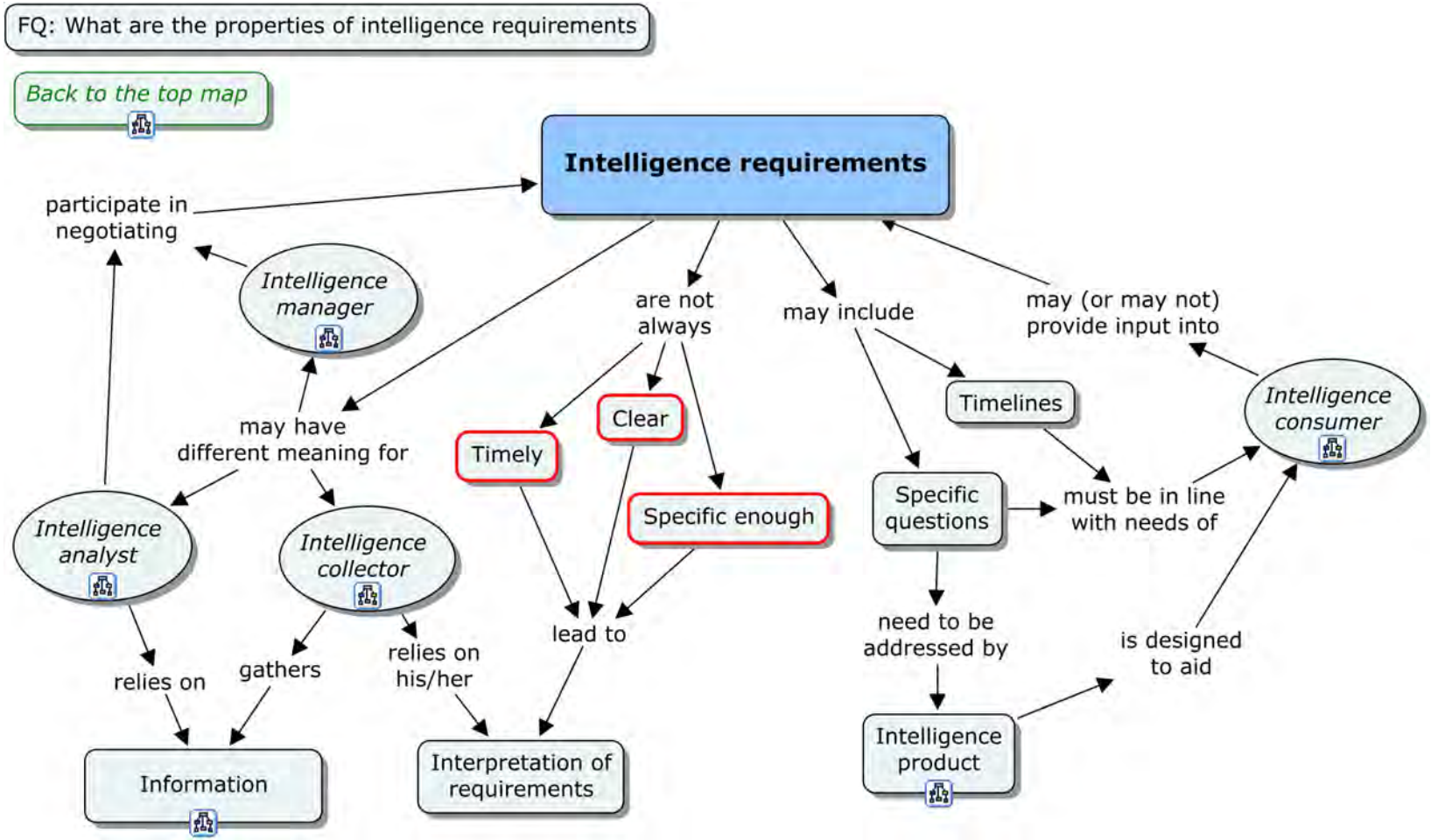

Figure 23: CMap #17: Intelligence requirements. Focus Question: What are the properties of intelligence requirements?

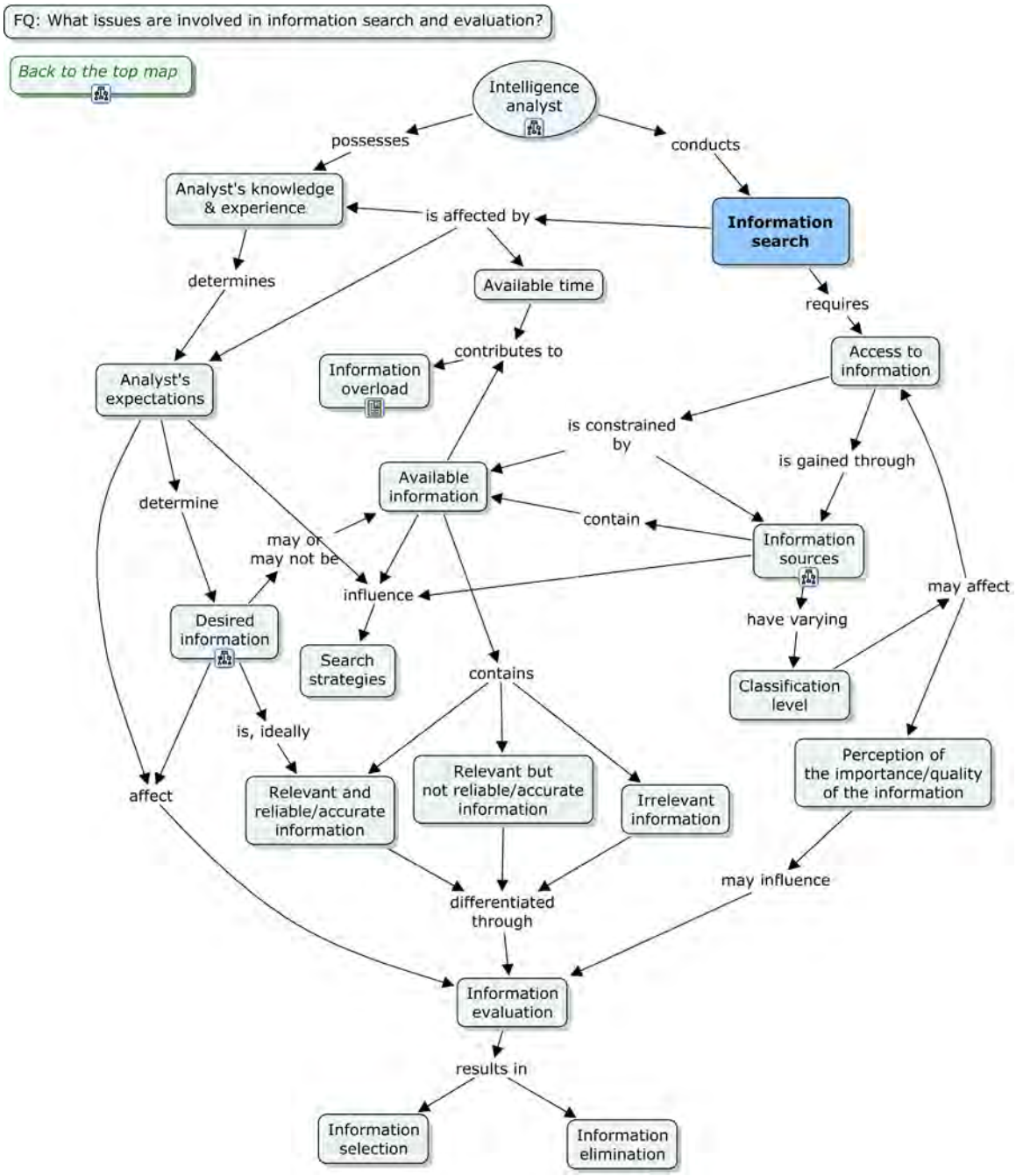

Figure 24: CMap 18: Issues in information search and evaluation. Focus Question: What issues are involved in information search and evaluation?

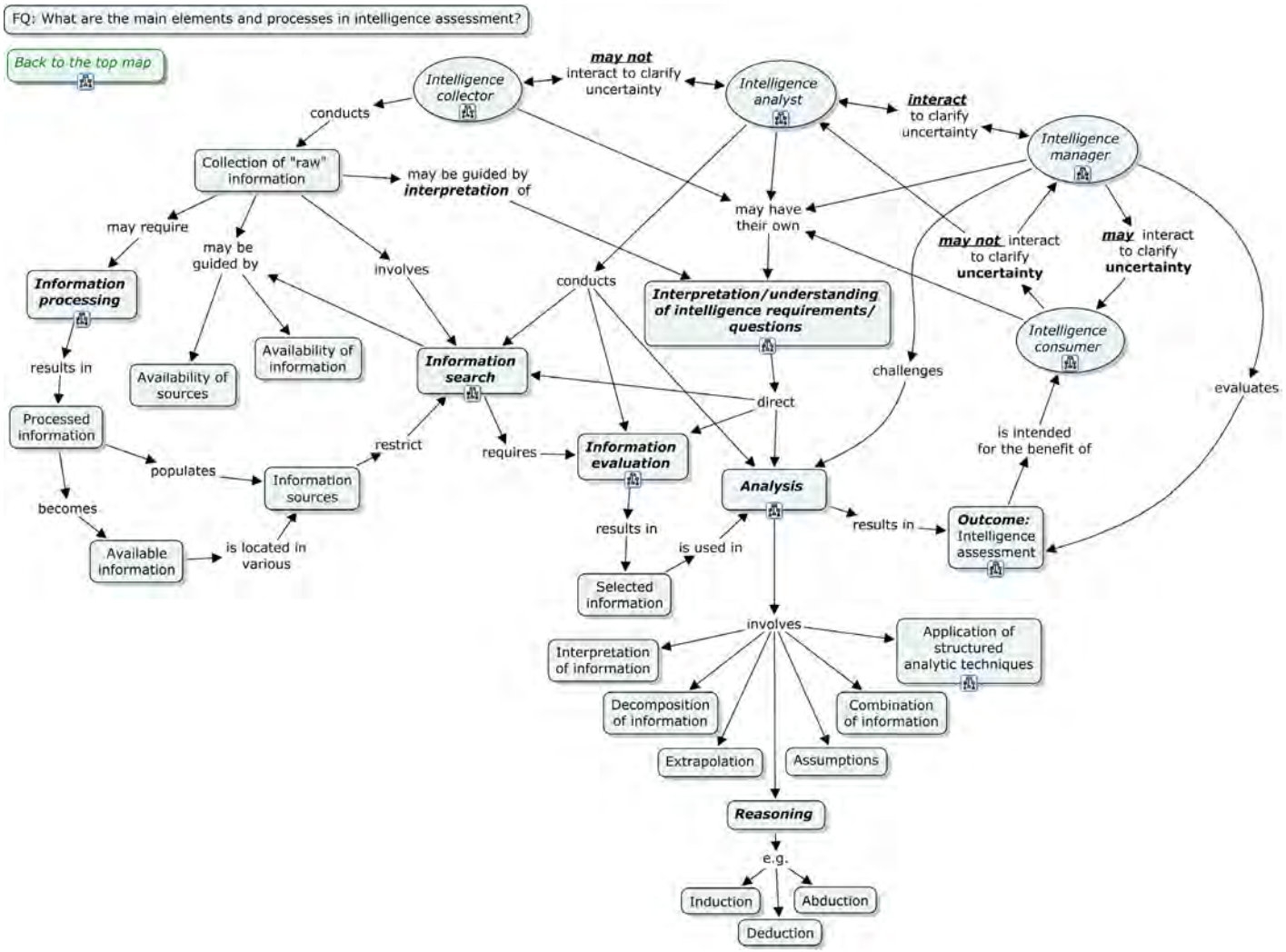

Figure 25: CMap #19: Main elements and processes in intelligence analysis. Focus Question: What are the main elements and processes in intelligence assessment?

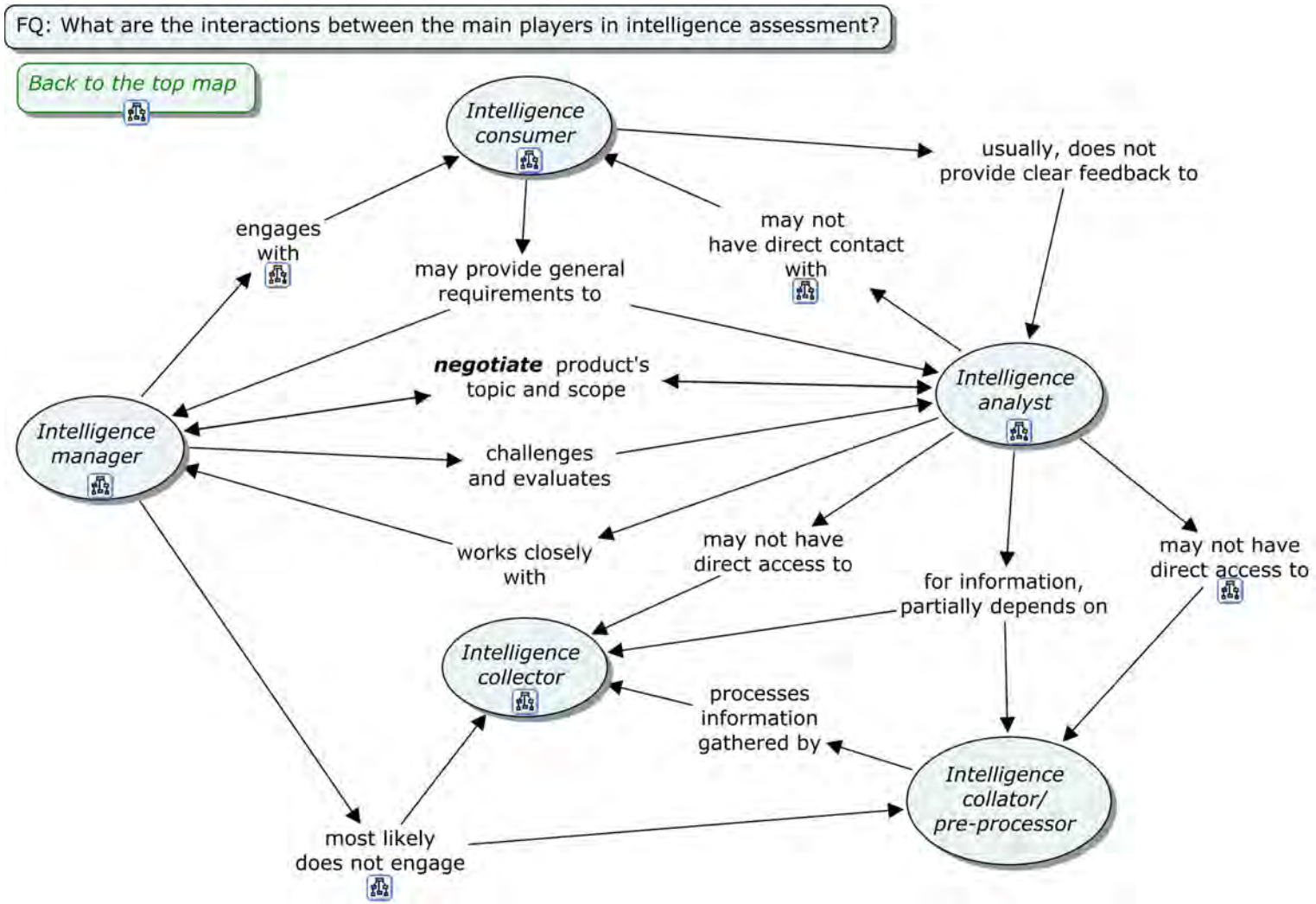

Figure 26: CMap # 20: Main players in intelligence analysis. Focus Question: What are the interactions between the main players in intelligence assessment?

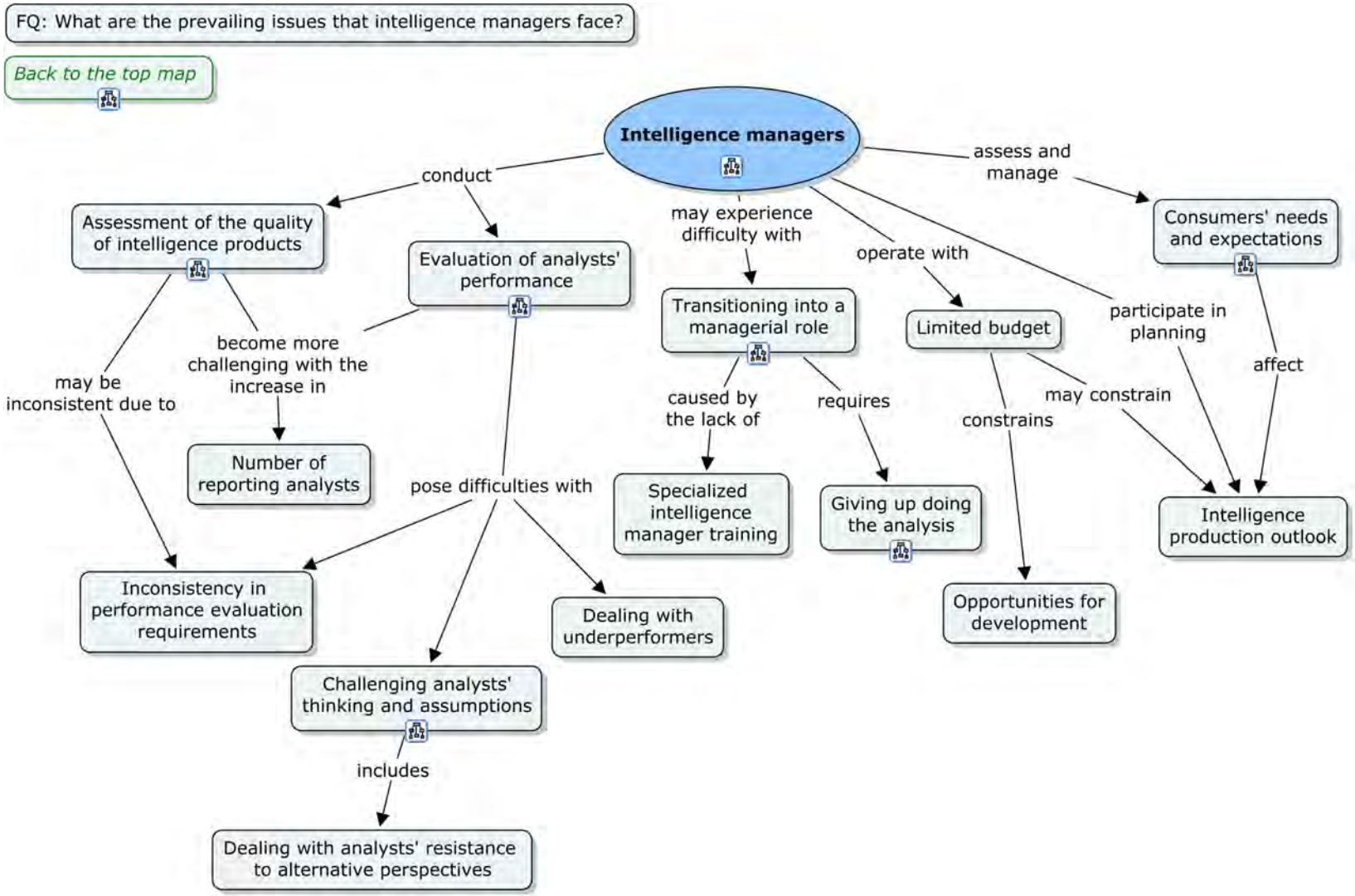

Figure 27: CMap #21: Management issues. Focus question: What are the prevailing issues that intelligence managers face?

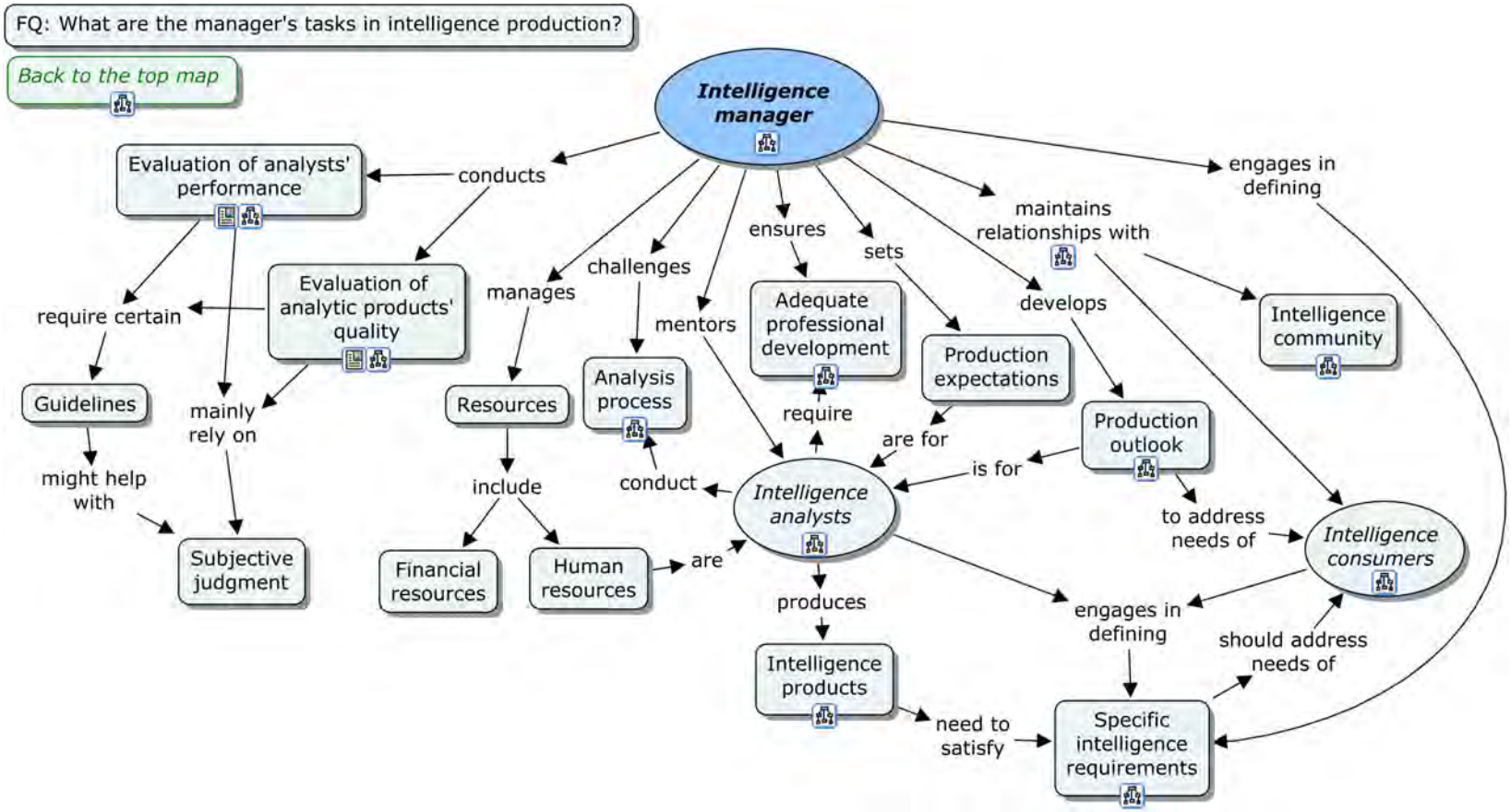

Figure 28: CMap #22: Managers' tasks. Focus Question: What are the manager's tasks in intelligence production?

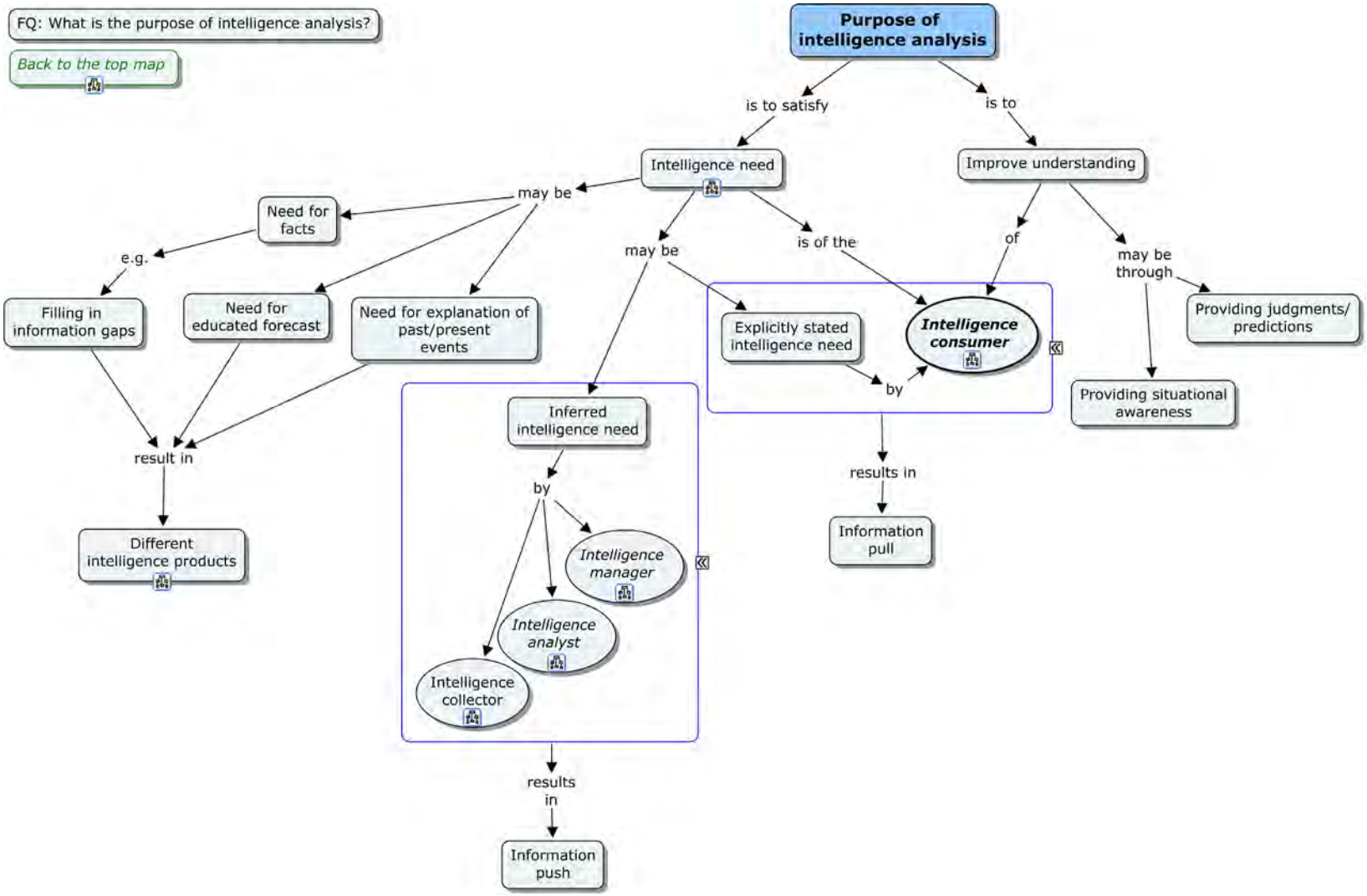

Figure 29: CMap #23: Purpose of intelligence analysis. Focus Question: What is the purpose of intelligence analysis?

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List of symbols/abbreviations/acronyms/initialisms

ACH	Analysis of Competing Hypotheses
ARP	Applied Research Program
CMap	Concept Map
CMapping	Concept Mapping
DRDC	Defence Research & Development Canada
IC	Intelligence Community
IHMC	Institute for Human and Machine Cognition
KM	Knowledge Model
TR	Technical Report

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A Concept Map Knowledge Model of Intelligence Analysis (U)
Un modèle de schéma conceptuel de la connaissance pour l'analyse du renseignement (U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Natalia Derbentseva; David R. Mandel

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
May 2011	76	43

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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(U) This Technical Report describes a Concept Map (CMap) Knowledge Model (KM) of intelligence analysis developed at DRDC Toronto. The CMap KM consists of a number of interlinked CMaps and over 100 additional resources (such as text documents, images, Internet links, etc.), organized into an interactive hyperlinked system, which serves as a resource depository and provides an easy access to relevant material. The CMap KM captures the research team's conceptual understanding of various issues relevant to intelligence analysis and brings together a number of pertinent topics. The authors' aspiration for this CMap KM is that it might serve as a springboard for further development of concepts essential to intelligence analysis and as a foundation for an intelligence analysis education program.

(U) Le présent rapport technique décrit un modèle de schéma conceptuel de la connaissance pour l'analyse du renseignement mis au point à RDDC Toronto. Ce modèle du schéma conceptuel de la connaissance est constitué d'un certain nombre de schémas conceptuels interconnectés et de plus d'une centaine de ressources additionnelles (telles que des documents−textes, des images, des liens Internet, etc.) organisées sous forme de système interactif hyperlié. Ce système sert aussi de dépôt de ressources, ce qui facilite l'accès aux documents pertinents. Le modèle du schéma conceptuel de la connaissance donne un aperçu de la compréhension conceptuelle de l'équipe de recherche sur différents enjeux liés à l'analyse du renseignement et rassemble un certain nombre de sujets pertinents. Les auteurs de ce modèle de schéma conceptuel de la connaissance aspirent à ce qu'il puisse servir de tremplin à un perfectionnement supplémentaire des concepts essentiels à l'analyse des renseignements et servir de fondation à un programme d'éducation en analyse des renseignements.

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(U) Concept map; knowledge model; intelligence analysis; knowledge representation; knowledge preservation

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